# A Bioeconomic Analysis of Existing and Proposed Fishery Management Alternatives to Control Sea Turtle Mortality In the Gulf of Mexico Shrimp Fishery

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# EXECUTIVE SUMMARY

The General Bioeconomic Fishery Simulation Model (GBFSM) was used to examine the effectiveness of four sea turtle conservation measures proposed for the Gulf of Mexico shrimp fishery. The intent of each of the alternatives is to reduce the real days fished in the nearshore zone, where turtle mortalities lead to stranding events. The model was used to allocate the real days fished and to consider the rents generated under each of the proposals. Each simulation assumed a shrimp loss to the fishery due to the use of prescribed turtle excluder devices (TEDs) of 6.75% per tow over a 25-year period. The base case is the set of current management regulations (CMR) for the shrimp fishery. The simulations in this report were used to evaluate the potential effectiveness of each proposal and the associated costs to the shrimp harvesting industry.

The Texas Shrimp Association (TSA) and LGL Ecological Research Associates, Inc. (LGL) have proposed a management alternative to limit net size of 100 ft of total headrope in the turtle conservation zone (nearshore); TEDs of any type would be acceptable. Nets in the offshore zone could be pulled without any TEDs. Under the (TSA/LGL) in Texas and Western Louisiana (W. Louisiana), effort increases relative to the CMR in the nearshore (6% and 3%, respectively) and offshore (11% and 7%, respectively). Marine turtle mortalities in the offshore zone should increase because of an increase in real days fished and the elimination of the requirement to use TEDs in this zone. This proposed management alternative could result in an increase in a net benefit of $19.5 million relative to the CMR.

Discussions between NMFS and LGL Ecological Research Associates resulted in a proposed management alternative (LGLM) that modified the TSA/LGL by restricting vessels greater than 60 ft in length from fishing in the nearshore zone. Under the LGLM, nearshore effort declined in W. Louisiana (46%) and Texas (90%) while offshore effort increased in W. Louisiana (60%) and Texas (23%) relative to the CMR. Turtle strandings have been shown to increase during the three weeks prior to and immediately following the opening of the Texas Closure in July of each year. If only this period is examined, then a 93% (Texas) and 33% (W. Louisiana) reduction in real days fished occurs in the nearshore zone. The large increase in real days fished in the offshore zone could potentially increase turtle mortality in Texas and Louisiana since TED equipped nets would not be required. Total net benefits to Texas and Louisiana shrimp harvesters would increase by $69.7 million under this management option.

A proposed restricted turtle excluder device management plan (R_TED) was developed by NMFS in March 1995 to restrict the use of soft TEDs and bottom opening hard TEDs in areas of elevated strandings and to subsequently close statistical zones to shrimp fishing for 30 days if turtle strandings continued to exceed a minimum level (the 30 day closure was not considered in this report). For the Restricted TEDs proposed management alternative (R_TED), fishing effort relative to the CMR does not change. The R_TED may reduce turtle mortality if top-opening, hard grid turtle excluder devices are more effective than soft or bottom-opening hard grid turtle excluder devices. Depending upon the shrimp loss scenario, this proposed management alternative could result in an increase in net benefits of $0.004 million.

The Temporary Effort Reduction proposed management alternative (TER) was designed by NMFS to reduce turtle mortalities in the Texas nearshore zone by prohibiting fishing 3 weeks

both before and following the Texas Closure when marine turtle abundance is the highest. A 42% reduction would occur in overall fishing effort in the nearshore zone of Texas. If only the period of the closure is considered, then a 95% reduction in real days fished occurred. However, under the TER, real days fished in the offshore zone of Texas increase 2% overall, and 33% during the time period of the 6 week special closure. In the Louisiana nearshore zone, there is no change in days fished and no expected change in turtle mortality. This proposed management alternative could result in an increase in net benefits of $2.8 million when compared to the CMR.

None of the proposed management alternatives address the underlying common property problem that is generating the unacceptably high incidental takes of sea turtles by the shrimp fishery. That is, with clearly defined, enforceable property rights for shrimp in the sea, total shrimp fishing effort would be reduced, total net benefits to the nation would be increased, and the incidental harvest of sea turtles would decline. Without a rights-based fishery management alternative, positive net benefits would attract new fishing vessels into the fishery causing effort levels to increase and further exacerbate the bycatch problem. In the case of negative net benefits, existing shrimpers would be forced out of the fishery without any increase in benefits to the nation. In either case, not addressing the common property problem in the shrimp fishery will cause managers to revisit the sea turtle bycatch and mortality problem in the future with more restrictive and costly regulations.

# INTRODUCTION

The five species of marine turtles listed as either endangered or threatened under the Endangered Species Act (ESA are an incidental harvest or bycatch in the Gulf of Mexico shrimp fishery. This shrimp fishery is based on an unlimited access common property resource. This has resulted in overcapitalization of the fishing fleet and generation of excessive shrimp fishing effort levels. Overcapitalization of the shrimp fishing fleet and its accompanying level of fishing effort results in turtle bycatch and its associated mortality. Annual estimates have ranged from 11,000 turtle mortalities (Henwood and Stuntz, 1987) to 44,000 turtle mortalities (National Research Council, 1990) per year in shrimp trawls. The National Research Council (1990) study identified the shrimp fishery as the primary cause of turtle mortality in the Gulf of Mexico.

Under the authority of the ESA, the preferred alternative of the National Marine Fisheries Service (NMFS) to reduce the incidence of turtle mortality associated with shrimp trawls was the adoption of a turtle excluder device (TED) in the shrimp trawl. The presently existing TED regulations were required throughout the Gulf of Mexico by 1991. If properly installed, the TED reduces the catchability of sea turtles by shrimp otter trawls without a significant reduction in the trawl's ability to harvest shrimp.[4] With the overcapitalization presently existing in the shrimp fishing fleet, this reduction in shrimp fishing effort effectiveness does not reduce the total shrimp harvested by the fleet. However, the TED regulations do impose costs on the harvest sector (Griffin and Oliver, 1991). The incidence of these costs falls primarily on the crew and the owner-operator or captain of the shrimp fishing vessel.

Even with TEDs in place on shrimp vessels operating in both nearshore and offshore waters of the Gulf of Mexico, elevated turtle strandings still occurred in Texas (statistical zones 18 to 21) and W. Louisiana (west of the Mississippi River including statistical zones 13 to 17) during 1990, 1994, and 1995. As a result, NMFS conducted a consultation on the effects of the fishery on endangered species, as required by Section 7 of the Endangered Species Act (ESA). The consultation concluded that the elevated strandings were the result of intense nearshore shrimping effort in areas of high sea turtle abundance, as well as use of either ineffective or illegal TEDs (November 14, 1994). Consequently, NMFS proposed a management plan (R_TED) in March 1995 (and imposed as an emergency rule in May 1995) to increase restrictions on allowable TED gear in areas of elevated strandings and subsequently to close statistical zones to shrimp fishing for 30 days if turtle strandings continued to exceed a defined level. In response to these emergency restrictions, the House Appropriations Bill for the Department of Commerce directed NMFS to "seek . . . recommendations and analysis . . . , including a detailed assessment of the economic impact on the affected shrimp fishing industry."

Since the adoption of the R_TED, three other management alternatives have been proposed for consideration. In April, LGL Ecological Research Associates, Inc., under contract with the Texas Shrimp Association, completed a study of existing data bases and developed an alternative (TSA/LGL) to the current management regulations (CMR) (Gallaway et al. 1995). LGL Ecological Research Associates concurred with NMFS that elevated strandings documented

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[4] The extent of the reduction in shrimp harvest per tow ranges between 14 percent and 0.7 percent with a weighted average of 6.7 percent (Renaud, et al., 1992).

during 1994 were the result of intensive nearshore shrimping effort, and they suggested that inshore effort contributed to the strandings. Subsequent discussions between NMFS and LGL Ecological Research Associates resulted in an alternative proposal (LGLM) that modified the TSA/LGL. The third management alternative was developed by NMFS because data indicated peak strandings in nearshore waters three weeks prior to and following the Texas Closure. This temporary effort reduction management alternative (TER) to reduce effort in nearshore waters is also considered in this report.

This report provides an assessment of the costs and benefits to the shrimp harvesting sector and the reallocation of shrimp fishing effort that will occur under each of the four management alternatives. Although some alternatives have both Gulf of Mexico and South Atlantic zones, only the Gulf of Mexico will be discussed. The report provides a brief description of the complexity of the shrimp fishery and the need for a sophisticated simulation modeling approach. This section will also explain the concepts of the simulation modeling approach utilized in this analysis. In the second section, regulatory differences between the CMR and the four management alternatives will be presented. The third section discusses the effects of the CMR and the four management alternatives on the reallocation of fishing effort, followed by a discussion of the present value of rents. The outcomes will then be summarized in the conclusion.

A separate analysis for the proposed south Atlantic regulations is beyond the financial resources and time constraints of this project. The method of analysis used in this report has never been applied to the shrimp fisheries that exist in the south Atlantic region. Extensive biological and economic data collections and analyses would have to be undertaken to develop estimates of the parameters used by the model. Additional funding and time would have to be allocated to determine the extent of the costs to the nation of applying these alternative regulations to the south Atlantic shrimp fisheries.

## METHOD OF ANALYSIS

The shrimp fishery in the Gulf of Mexico is a very complex fishery. Brown, white, and pink shrimp are harvested by a heterogeneous shrimp fleet consisting of generalist vessels that harvest shrimp and other commercial species, specialist vessels that harvest shrimp exclusively, and boats[5]. Many factors, both biologic and economic affect the fishery. Real shrimp price varies from season to season and year to year both with the highly variable relative abundance of shrimp and the adverse effects of imports. Fuel costs increased significantly in the 1970s and decreased slightly in the 1980's affecting variable costs. Insurance premiums that have steadily increased over time have affected fixed costs. In addition, alternative finfish fisheries in the Gulf of Mexico have become increasingly regulated leading to shortened fishing seasons and creating incentives to enter the shrimp fishery even though relative prices may not be particularly attractive. Other industries such as the secondary and tertiary oil recovery fields in W. Louisiana

[5]A vessel is defined by the U.S. Coast Guard to be a registered fishing craft in excess of five net tons. A boat is defined by the U.S. Coast Guard to be a fishing craft less than five net tons. In this report the term vessel is applied to both vessels and boats.

declined in the 1980's and may have reallocated labor to the shrimp fishery. Thus, simulation modeling must be employed to separate effects of management regulations from effects of the other endogenous and exogenous variables affecting the shrimp fishery. Holding other exogenous variables constant, the impacts of a proposed or existing management regulation can be determined by altering only those variables directly affected by the rule. The General Bioeconomic Simulation Model (GBFSM) developed by Grant, Isakson and Griffin (1981) can be used to estimate effects of proposed regulations in terms of total harvest of shrimp (by species, size class, and season), total rents (fishing costs, and revenue in the fishery), and the distribution of rents (Griffin et al. 1993; Hindrickson and Griffin 1993; Krauthamer et al. 1987; Lambregts and Griffin 1991; Warren et al. 1981;)

### *Policy Analysis*

Initially, the model was set at an equilibrium total fleet size with a given effort distribution based on actual shrimp fishery data from the period 1986-1989. These years were selected because the Texas Closure was in effect only out to 15 miles, the 1-4 fathom white shrimp fishery was open to allow for the harvesting of large white shrimp and TEDs were not required. A 25-year simulation period was used to evaluate the effects of the current and proposed management regulations. Rent for each management regulation is discounted over the 25 years as the industry adjusts toward a new equilibrium position. Rents of vessel owners and crew were assumed to be zero in the fishery before regulations were introduced. The introduction of a regulation would disturb the industry equilibrium and negative or positive rents would be incurred. Negative rents would cause some shrimp vessels to leave the industry while positive rents would cause additional shrimp vessels to enter the fishery. The analysis consisted of comparing results of the simulation output for the CMR to the simulation output for the four management alternatives (TSA/LGL, LGLM, R_TED and TER).

### *Model Dimensions, Data, Tuning and Validation*

The GBFSM has both biological and economic submodels. The biological submodel represents the recruitment of new organisms, spatial and temporal movement, growth and mortality (natural and fishing). This submodel represents fishing effort exerted on each species by vessel class, depth zone, area, and time frame. Nominal days fished read into the model are converted to real days fished based on appropriate changes in the relative fishing power of vessels as discussed below. The economic submodel represents monetary costs of fishing, value of harvest, and rent to the fishery. The economic submodel is built "on top of" the biological submodel and calculates economic effects based upon the biological effects of any management alternative input into the model.

The dimensions of GBFSM are as follows:

1. Fishing areas: W. Louisiana (statistical zones 13-17)
   Texas (statistical zones 18-21)
2. Depths fished: inshore
   0-5 fathoms

6-10 fathoms
11-25 fathoms
>25 fathoms

3. Species of shrimp: Brown shrimp (*Penaeus aztecas*),
White Shrimp (*P. setiferus*),

4. Sizes of shrimp: <20 tails/lb
21-30 tails/lb
31-50 tails/lb
51-67 tails/lb
68-95 tails/lb
96-135 tails/lb
136-192 tails/lb

5. Class of vessel: 1 >= 40 ft in overall length
2 >40 ft and <=55 ft vessel length & <36 yd total footrope
3 >40 ft and <=55 ft vessel length & >36 yd total footrope
4 >55 ft vessel length & <36 yd total footrope
5 >55 ft vessel length & >36 yd total footrope

6. Model time steps: 4 time steps/mo for 48 time steps/yr

Vessels fish in either Texas or W. Louisiana. Vessels cannot change fishing areas in the GBFSM, but they can change depth zone of operation within an area.

Nominal days fished are entered into GBSFM and changed to real days fished as follows: Vessel length and gear size affect the fishing power of a shrimp vessel. Each vessel's fishing power is calculated relative to that of a standard vessel 68 ft. long using nets with 53 yds of total footrope. Thus, relative fishing power ($RFP_i$) of vessel $i$ is calculated as

$$RFP\ i = \left(\frac{\text{footrope}_i}{53}\right)^{0.34} \left(\frac{\text{length}_i}{65}\right)^{0.31}.$$

Footrope (yds) and vessel length (ft) are the only factors contributing to relative fishing power. Real days fished is calculated by multiplying nominal days fished by $RFP_i$.

For the CMR and the four management alternatives, the shrimp loss per tow caused by TEDs is assumed to be 6.7% (Renaud et al. 1993). Clogged nets will reduce the days fished by vessels using TEDs by 3.5% as compared to vessels without TEDs (Renaud et al. 1990). During their down time, they do not catch shrimp, but are assumed to accrue variable cost at a rate of 40% of their costs related to effort. TEDs have been assumed to require repair and replacement each year at an annual cost that depends on vessel type. For vessel class 1, the cost is $500 per year. For vessel class 2 and 3, the cost is $1,000 per year. For vessel class 4 and 5, the cost is $2,000 per year. The model does not presently accommodate different TED costs for soft and hard TED designs. The reduced catchability by the TED-equipped shrimp gear does not induce any additional shrimp mortality; shrimp are assumed to continue growing, migrating offshore, and

are subject to recapture.

To tune the model, most coefficients were taken from the literature or from state and federal agencies (Griffin and Oliver 1991). Other coefficients such as movement of shrimp were nonexistent and derived through tuning. That is, various biological coefficients within the model were adjusted until simulated landings match actual average shrimp landings.

Data on actual shrimp landings for the equilibrium period 1986-1989 were obtained from NMFS landings data. This data is aggregated to landings by area, species, region, size class, depth zone, and month. Fishing effort (nominal days fished, or 24 hours of drag time) was derived from the effort expansion data developed by Griffin and Shah (1995) and is aggregated by area, species, vessel class, depth zone and time step. Fishing effort is set exogenously in the model to equal average days fished for the 1986-1989 historical period.

## *Current Regulations and Proposed Management Alternatives*[6]

Once properly tuned, the GBFSM was reconfigured to conform to the CMR in the Gulf of Mexico shrimp fishery and to each of the proposed management alternatives designed to reduce sea turtle mortality in the nearshore. Comparisons of simulated results between each proposed management alternatives and the CMR will determine their relative effects on the shrimp harvesting sector. Each regulation and proposed management alternative is discussed below.

### *CMR - Current Management Regulations*

Currently, three regulations are unique to Texas. First, the current Texas Closure adopted in 1981 closed the federal waters of the Gulf of Mexico shrimp fishery to coincide with the closure of state waters. Second, in 1990 Texas closed the 1 to 4 fathom nearshore which had previously been open to fishing for large white shrimp during the closure. Thus, from 1990 until the present, the closure has included all waters from the beach to a distance of 200 nautical miles. Third, was the recent adoption of a license limitation program in the Texas inshore bay and bait shrimp fishery, eventually limiting the number of boats operating in state waters.

### *TSA/LGL -- TSA and LGL Proposed Management Alternative*

This proposal by TSA and LGL to reduce marine turtle bycatch includes:

A) A sea turtle conservation zone in all the Gulf of Mexico including inshore and nearshore waters out to a distance of 10 kilometers (6.2 statute miles) except for statistical areas 17 and 18 where the offshore boundary would extend to 18 statute miles.

B) The extent of the sea turtle conservation zone in the Tortugas-Sanibel pink shrimp fishing grounds offshore southwest Florida would also be increased beyond ten kilometers.

C) Within the sea turtle conservation zone, TEDs would be required at all times and places

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[6]Personal communication, David Bernhart, Endangered Species Division, Southeast Regional Office, National Marine Fisheries Service, 9721 Executive Center Drive North, St. Petersburg, FL.

and nets could not exceed 100 feet of total headrope as measured from outside hanging to outside hanging; trynets with 15 ft or less of headrope would be exempt from TED requirements.

D) Night fishing would be prohibited in statistical areas 17 to 21 in the sea turtle conservation zone.

E) The sea turtle conservation zone would be considered critical habitat and as such all user groups[7] would be included in any subsequent emergency time or area closures of the zone.

F) Vessels operating in the offshore waters beyond 10 kilometers would not be required to use TEDs.

### *LGLM -- Modified LGL Proposed Management Alternative*

In addition to the conditions specified in the TSA/LGL, the LGLM would prohibit vessels 60 ft or longer from operating in the sea turtle conservation zone. A vessel length of 55 ft in the Vessel Operating Units File based on U.S. Coast Guard registered length was assumed to be equivalent to a 60 ft length overall for a vessel.

### *R_TED – Restricted TED Proposed Management Alternative*

This alternative is presently in effect as an emergency regulation.

Northern Gulf interim special management areas are established off W. Louisiana and Texas from zone 13 through zone 20 seaward of the COLREGS line out to ten nautical miles. In this interim proposed management alternative, TEDs are required for all shrimp fishing vessels at all times and places. Within the interim special management areas, two levels of rules go into effect if strandings exceed a defined incidental take level equal to twice the weekly historical strandings average (based on data collected between 1991 and 1993).

A) The first level implementation requires publication of a temporary rule that would:

1. Prohibit the use of soft TEDs.

2. Prohibit the use of hard TEDs with bottom escape openings.

3. Prohibit the use of trynets with a headrope length greater than 12 ft (3.6 m) or a footrope length greater than 15 ft (4.5 m) unless the trynet is equipped with an approved top-opening hard TED. Smaller trynets can be used without TEDs.

4. Prohibit the use of a webbing flap that completely covers the escape opening on top-exiting TEDs.

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[7] User groups according to the LGL proposed rule include any and all activities any individuals perform that are suspected to have impacts on marine turtles. These include shrimp trawling, the capture of finfish by commercial and recreational fishermen, long lining for fish, dredging, boating, oil rig removal, oil and gas explorations and military maneuvers involving explosives in the marine environment.

5. Remain in effect for 30 days. Changes in the rule or extensions of the rule could be required through additional 30 day periods.

B) A second level of restricted TED implementation would be invoked if strandings continued and would include a temporary rule that would:

1. Close areas from the COLREGS line out to ten nautical miles within the statistical zone of elevated strandings, and close the contiguous statistical zones or portions of the contiguous zones, as deemed necessary.

2. Remain in effect for 30 days. Changes to the size and extent of the closure, and any extension of the closure, could be required for an additional 30 days.

C) Outside the interim special management areas, in zones 1 through 12 and 21, additional actions could be taken if elevated strandings occurred:

1. Enforcement could be increased.

2. Elevated strandings for one month could lead to implementation of higher enforcement efforts or level one rules similar to those for the interim special management areas.

3. As with the interim special management areas, two additional weeks of high strandings following level one rules could lead to closures.

*Temporary Effort Reduction Proposed Management Alternative*

Under this proposed management alternative, NMFS would amend the regulations protecting sea turtles (50 CFR parts 217 and 227, subpart D) to:

A) Eliminate by December 31, 1996 the use of soft turtle excluder devices (TEDs) which have demonstrated reduced effectiveness under actual commercial fishing conditions.

B) Require by December 31, 1996 the use of TEDs in try nets with a headrope length greater than 12 ft (3.6 m) or a footrope length greater than 15 ft (4.6 m).

C) Establish shrimp fishery sea turtle conservation area in the northwestern Gulf of Mexico consisting of the offshore waters out to 10 nautical miles (nm) (18.5 km) along the coasts of W. Louisiana and Texas from the Mississippi River South Pass to the U.S.-Mexico Border.

D) Implement the TED requirements of items (A) and (B) and prohibit the use of bottom-opening hard TEDs in the sea turtle conservation area if a final rule becomes effective.

E) Reduce nearshore shrimp trawling effort by prohibiting fishing in the Texas portion of the sea turtle conservation area for a time period approximately 3 weeks prior to and 3 weeks following the Texas closure by shrimp vessels greater than 55 ft (18.3 m) in length (60 ft length overall) and by shrimp vessels with a total headrope length among all nets rigged for fishing greater than 100 ft (30.5 m).

### *GBFSM Simulation Constraints*

The GBFSM as currently configured constrains the extent of the cost-benefit analysis that can be accomplished for these proposed management regulations. For example, the model includes only two areas, W. Louisiana west of the Mississippi River (statistical zones 13 to 17), and Texas (statistical zones 18 to 21). As a result, analysis of the impacts of closing selected statistical zones within an area is not possible.

The model is presently configured to investigate current regulations and proposed management alternatives that affect the ability of shrimpers to harvest from different depth zones. The sea turtle conservation zone, the sea turtle conservation area, and the interim special management areas are defined solely by their distance from shore or the COLREGS line. These kilometer, statute and nautical mile definitions do not correspond to existing depth zones in the Gulf of Mexico. For this study, the GBFSM has been modified to approximate these distances from shore using depth zones between areas. For example, in W. Louisiana the sea turtle conservation zone has been defined to correspond to a depth of five fathoms, while in Texas it corresponds to a depth of ten fathoms. Since depth zones and distances do not exactly correspond, some estimation bias in costs and benefits will result. Also, it is not possible to distinguish between a sea turtle conservation zone of 6.2 statute miles and a sea turtle conservation area or an interim special management area of 10 nautical miles using the GBFSM as presently configured.

The GBFSM assumed that TEDs are used by all shrimp vessels both inshore and offshore at all times except in the offshore zone for the TSA/LGL and the LGLM. Also, in this analysis, the same level of efficiency in harvesting shrimp is assumed for all TED types. Finally, the GBFSM is not presently configured to include the impacts of the inshore Texas license limitation program.

Ideally, sea turtle population dynamics should be incorporated into the GBFSM. The model could then generate an estimate of bycatch for each species of sea turtle resulting from shrimp fishing effort for each region and depth in the Gulf of Mexico. The probability of active, comatose, and dead turtles could be calculated based on existing observer data, and could be incorporated into the model to determine the number of turtles that would be discarded. Using this estimate and the probability of a turtle stranding, the number of times the incidental take level was exceeded could be estimated by the model. The GBFSM could then calculate endogenously the number of times incidental take levels would be exceeded over time at various levels of shrimp abundance, prices, and operating costs. The impact on costs and benefits of each trigger mechanism for a management scenario could be determined by the model. However, estimates of sea turtle population size for the five species being considered in this analysis, the probabilities for comatose or dead turtles in shrimp trawls, or the probability of exceeding an incidental take level do not presently exist. Although the model is capable of generating sea turtle bycatch levels in the shrimp fishery, this lack of basic data on sea turtle populations sizes and population dynamics prevents it from being included in the model.

The R_TED and the TER proposed management alternatives require that the shrimp fishermen convert to top opening hard TEDs. No data exist on the percent of the fleet that use various TED types. However, based on enforcement observations during 1995, approximately

10% were soft TEDs and 90% were hard-grid TEDs (Bernhart, 1995). Therefore, for the purposes of this analysis, fishing craft in the sea turtle conservation zone are assumed to use a mix of TED types in their fishing gear. As a result, GBFSM was modified to include the costs of conversions to top-opening, hard TEDs each year for the R_TED. However, for the TER, the conservation to the top-opening hard TED is a one time conversion and, therefore, no cost conversion is accounted for.

Other causes of turtle mortality are not addressed in this analysis. The existing GBFSM is not configured to incorporate other fisheries or marine activities that could generate turtle strandings. Without better data or the time and financial resources to revise the model, these causes of sea turtle mortality will be implicitly assumed constant in this analysis. However, the TSA/LGL and LGLM specifies the sea turtle conservation zone as critical habitat and a closure of this area would necessitate the cessation of all activities that are known to impact sea turtles. These costs to society cannot be incorporated into the GBFSM simulations. Thus, estimates of costs will be understated in the evaluation of the TSA/LGL and LGLM and rents will therefore be overestimated.

The GBFSM does not at present include enforcement subroutines. Compliance levels for each management alternative are assumed to be 100 percent for the shrimp fishery. Since neither the U.S. Coast Guard nor NMFS enforcement are likely to receive a budget increase to insure compliance with these management alternatives, enforcement is considered to be a sunk cost in this analysis and are not considered to be different among alternatives. As a result, the net benefits would be overestimated by a constant amount relative to the CMR.

The TSA/LGL and LGLM require a restriction on night fishing within zones 17-21 of the sea turtle conservation zone. Currently, night fishing is already restricted out to 7 fathoms in Texas waters, most of the area covered under these proposals. As presently configured, the GBFSM cannot incorporate this restriction on fishing activity.

## SIMULATION RESULTS

Figures 1 to 16 present the results of the GBFSM simulations of the proposed management alternatives: Effects on rent and real days fished for each area are first shown by vessel class and then the combined effect on real days fished by depth zone. Results for Louisiana are presented first (Figures 1 to 8), followed by results for Texas (Figures 9 to 16). Finally, the overall impacts are reviewed (Tables 1-6). In the discussion, the CMR is considered to be the base case against which each of the four proposed management alternatives are compared.

### *W. Louisiana*

The TER and R_TED analyses were virtually identical to the CMR in W. Louisiana and will not be discussed. Because the TER affects only the Texas shrimp fishery, the TER and CMR were identical in W. Louisiana. The R_TED, presently in effect, did require an increase of TED costs of 10% relative to the CMR, but the simulation results in W. Louisiana were not significantly affected by this small change.

Under the CMR and the TSA/LGL, rents tend to be in equilibrium over the 25 year period of the analysis (Figure 1a) and fluctuate around a central point. The LGLM is initially out of equilibrium in Figure 1a, but by year 13 appears to have achieved its long run equilibrium. The total days fished for all vessel classes tends to be relatively constant for all alternatives except the LGLM (Figure 1b). Initially, real days fished rises under the LGLM due to the higher rents generated in the fishery and then declined as the rents become negative before settling on a new stable equilibrium level. The TSA/LGL showed the second largest increase in real days fished relative to the CMR.

The vessel size classes benefiting from the proposed management alternatives versus those suffering the costs can be better understood by an analysis of the change in rents and real days fished for each vessel size class (Figures 2 to 6). Only the LGLM's rents for each vessel size class differ substantially from the CMR (Figures 2a to 6a). Under the LGLM, the vessels in size class 4 and 5 are precluded from operating in the nearshore depth zone. The displaced effort from the nearshore is redistributed to the offshore area. Initially, this reduces effort in the nearshore (Figure 7b) which allows those vessels remaining in the nearshore to have a higher landings per real day fished. Less fishing pressure in the nearshore also allows more shrimp to escape to the offshore zone and to grow to a larger size. This causes landings per real day fished to increase in the offshore zone despite the increased effort in that zone (Figure 7c).

Real days fished continue to increase for all vessel classes under the LGLM through year 5 and as a result rent declines for all vessel classes (Figures 2 to 6). Rents become negative for vessel classes 1, 2 and 5 and their real days fished begin to decline until year 13 when the rent and real days fished become relative stable. Vessel classes 3 and 4 fair much better. Their rent is always positive (except for vessel class 4 in year 9) through the 25-year period. As a result their real days fished continue to increase through the 25-year period.

Under the TSA/LGL, real days fished for vessel class 4 and 5 tend to be slightly higher than the CMR (Figures 5b and 6b) and less than the CMR for vessel classes 1, 2, and 3 (Figures 2b, 3b and 4b). Vessel class 4 and 5 are more likely to spend a larger percentage of their fishing time in the offshore depth zone. Under the proposed TSA/LGL management alternative, vessels larger than 55 ft (60 ft length overall) are not precluded from operating in the nearshore depth zone provided they use nets with less than 100 feet of headrope. Also, in the offshore depth zone, these vessels are no longer required to use turtle excluder devices in their nets. As a result, both operational down time due to net clogging and operating costs should be lower while their landings levels should be higher. As a result, rents should be slightly higher and days fished should increase relative to the base case.

Figure 7 presents the results of the simulation model for the inshore, nearshore and offshore depth zones for W. Louisiana. In the inshore depth zone (Figure 7a), the proposed TSA/LGL is nearly identical to the current management regulations. In the nearshore depth zone (Figure 7b), real days fished for the TSA/LGL diverges slightly from the CMR. Real days fished are slightly higher than those for the CMR over the 25 years of the simulation. In the offshore depth zone real days fished increase slightly more for TSA/LGL than the CMR (Figure 7c). The LGLM has the greatest change in real days fished relative to the base case. In the inshore depth zone, real days fished are greater than the CMR after year 3 of the simulation (Figure 7a). In the nearshore zone, real days fished are approximately half the CMR for the entire simulation run (Figure 7b).

In the offshore depth zone, real days fished are higher than the CMR for the entire simulation run (Figure 7c).

Figure 8 is similar to Figure 7 except it only includes real days fished during the last week in April through the first week in August. The magnitude of real days fished in Figure 8 is less than that of Figure 7, but the relationship between the proposed management alternatives and the CMR is almost identical.

The LGLM does achieve the objective of reducing fishing effort in the nearshore zone in W. Louisiana better than any other proposed management alternatives or the CMR. Turtle mortality would be reduced in the nearshore zone. However, without a requirement to use TEDs in the offshore zone, total marine turtle mortalities could increase due to the increase in fishing effort.

### *Texas*

Rent for all vessel classes fluctuates between values of approximately $1 to -$2 million over most of the 25 years of the simulation (Figure 9a). Although at times counter cyclical, no single proposed management alternative results in substantially higher or lower rents relative to any other management alternative or the CMR. The TSA/LGL begins with a positive rent, whereas the CMR and the other proposed management alternatives begin with negative rents. Real days fished on the other hand indicate trends that differ from the CMR (Figure 9b). The TSA/LGL is higher than the CMR for the entire simulation since the initial positive rent attracts vessels into the fishery. Vessels owners find it easier to get into the fishery when rents are positive than to leave the fishery when rents are negative because the value of the vessel decreases when rents are negative and it is less costly to keep fishing than to sell the vessel. The TER has slightly lower real days fished than the CMR for most of the years. The other proposed management alternatives (R_TED and LGLM) are of similar magnitude or identical with the CMR.

Vessel classes that have positive or negative benefit from the proposed management alternatives can be better understood by an analysis of the change in rents and real days fished in each vessel size class (Figures 10 to 14). Rents are initially negative under the CMR and for each of the four proposed management alternative for vessel classes 1, 2 and 4. As a result, real days fished decline over the 25 years for each of these vessel classes. For vessel classes 2 and 4 a new rent equilibrium is achieved after year 10 under each proposed management alternative and the CMR.

Vessel class 4, however, does not achieve a new equilibrium over the entire 25-year period. Rents are negative under all proposed management alternatives for size class 4 vessels in Figure 13a. These negative rents seem to be declining over time, but have not returned to zero by the end of the simulation. As a result, real days fished in Figure 13b decline, but do not reach a new equilibrium level by year 25 of the simulation. Although rents are lower for both the LGLM and TER compared to the CMR (Figure 13a), days fished are slightly higher for LGLM but equal for TER (Figure 13b). However, the differences in real days fished between proposed management alternatives and the CMR are extremely small when compared to the differences in other vessel size classes. For example, real days fished varies between 50,000 and 70,000 for vessel class 5 in Figure 14b.

Vessel class 3 has positive rents through the 25-year period under the LGLM. This results in an increase in real days fished because vessel classes 4 and 5 no longer fish in the nearshore zone. Notice, however, that vessel class 3 has smaller amounts of real days fished than other vessel classes. This result is significantly different from W. Louisiana where vessel classes 2 and 3 increased approximately 25,000 real days fished. The Texas closure prevents this type of increase off Texas for vessel classes 2 and 3.

The TSA/LGL causes rents to increase for vessel class 5 for the first four years of the simulation (Figure 14). This occurs because TEDs are not used in the offshore zone and the Texas closure extends from the beach seaward 200 nautical miles. Positive rents attract more vessels into this size class and as a result real days fished increase through the fifth year. After year five, rents and real days fished basically stabilize.

Rents for vessel class 5 fluctuate around zero in Figure 14a. This implies that the proposed management alternatives do not significantly affect the long run equilibrium of the fishery for this size class vessel. Real days fished under the proposed TSA/LGL are higher than the CMR and lower under the proposed LGLM and TER management alternatives in Figure 14b. The proposed R_TED and the CMR are identical in terms of rents generated by the fishery in Figure 14a and real days fished (Figure 14b).

Real days fished by inshore, nearshore, and offshore depth zones are presented in Figures 15 a, b, and c for Texas under the CMR and each of the four proposed management alternatives. Although real days fished are generally declining from more than 25,000 to approximately 20,000 days fished, the CMR and each of the four proposed management alternatives are essentially the same in the inshore depth zone (Figure 15a). In the nearshore depth zone (Figure 15b), the LGLM substantially reduces real days fished from approximately 12,000 days fished under the CMR to less than 2,000 days fished. The TER also reduces real days fished from the 12,000 under the CMR to nearly 8,000 days fished. The R_TED does not affect real days fished relative to the CMR. Finally, the TSA/LGL results in a slight increase in real days fished in the nearshore zone (Figure 15b). In the offshore depth zone (Figure 15c), real days fished are approximately the same for the TER and R_TED and the CMR. The LGLM and the TSA/LGL are slightly higher than the CMR. Since vessels are exempt from using TEDs in the offshore depth zone, these increased real days fished are likely to increase turtle mortalities in this depth zone.

The TER is designed to close the Texas shrimp fishery three weeks both prior to and following the dates of the Texas Closure in order to reduce days fished in the nearshore depth zone during periods of high marine turtle abundance. Marine turtle abundance would decline through immigration of this nearshore zone before the heavy shrimp fishing pressure began with the opening of the Texas shrimp fishery. In Figure 16a, during the time period of the extended closure set by the TER, inshore effort declines over time with real days fished slightly higher under the LGLM than the other proposed management alternatives and the CMR. Real days fished for the TER and LGLM decline substantially relative to the CMR during this time period in the nearshore zone (Figure 16b). In the offshore zone (Figure 16c), real days fished increase for the TER and LGLM relative to the other proposed management alternatives and the CMR. Even though real days fished increase more under the TER, turtle mortalities should not increase as much as in the LGLM and TSA/LGL since nets must still be equipped with TEDs.

### *Present Value of Rent Differences*

The difference in present value of rent (PVR) generated under the CMR versus each of the four proposed management alternatives is presented in Tables 3, 4, and 5 for the owner and crew, for the owner, and for the crew, respectively. All of the proposed management alternatives resulted in an improvement in owner and crew total PVR for the shrimp harvesting sector (Table 3). Grand totals ranged from an increase of $4,000 to $69.7 million in PVR generated relative to the CMR. Within vessel size classes, some vessels generated increased PVR while others experienced losses. For example, under the TER (Table 3), PVR for all vessel size class improved except for vessel size class 4 operating in Texas. Vessel class 5 operating in W. Louisiana lost $56 million in PVR under the LGLM (Table 3). However, PVR improved by $69.7 million for all vessels in Texas and Louisiana under the LGLM.

Owners, in general, fared better than crews in capturing the change in PVR. Only under the TER did crews (Table 5) capture more of the change in PVR than the owners (Table 4). Tables 3 and 4 show no PVR generated in Louisiana under the TER. Crews received $3.3 million of the change in PVR generated in Texas (Table 5) and owners lost $0.5 million. Louisiana owners received $61 million of the change in PVR while Texas owners lost $1.5 million under the LGLM (Table 3). However, crews did better in Texas ($7.1 million) under the LGLM than in Louisiana ($3.1 million; (Table 3).

### *Index of Real Days Fished*

An index of real days fished (IRDF) calculated as the sum of real days fished over the 25-year period for each the proposed management alternatives divided by the sum of real days fished over the 25-year period for the CMR is presented in Tables 6, 7, and 8. An index less than one (greater than one) indicates that the proposed management regulation resulted in an aggregate total real days fished less than (more than) the CMR for the entire 25-year period .

The index in Table 6 indicates that real days fished increase under the TSA/LGL and the LGLM, remained constant under the R_TED and decreased under the TER. The TER has no impact on the W. Louisiana region (IRDF=1.0), but reduces the real days fished in Texas across all vessel size classes by 3% (IRDF=0.97). However, even though overall effort declined under the TER, real days fished did increase for vessel class 1 (IRDF=1.02), vessel class 2 (IRDF=1.02) and vessel class 4 (IRDF=1.01). It was the reduction in effort in vessel class 5 (IRDF=0.95) that caused overall effort in Texas and both regions combined to decline.

The R_TED had no effect on the real days fished generated for each vessel size class in Texas or W. Louisiana in Table 6 (IRDF=1.0 for all vessel classes). The incidence of the decline in real days fished under the LGLM fell in class 5 vessels in Table 6 for both Texas and W. Louisiana. Real days fished increased for all other vessel size classes with vessel class 3 in Texas increasing 140% (IRDF=2.40). However, vessel class 3 consists of only a small number of vessels. Under the TSA/LGL, effort increased for W. Louisiana (IRDF=1.03) and Texas (IRDF=1.07). However, in Louisiana, real days fished declined for vessel class 2 and 3 and for

vessel class 2 in Texas. Vessel class 4 in Louisiana (IRDF=1.11) and vessel class 5 in Texas (IRDF=1.10) both had increases in effort under the TSA/LGL according to Table 6.

Determining whether the proposed management alternatives achieve their objective of reducing shrimp fishing effort in the nearshore zone to reduce sea turtle mortality can be determined from Tables 7 and 8. Of the four proposed management alternatives, the LGLM (IRDF=0.10) and the TER (IRDF=0.68) achieved the stated objective of reducing sea turtle mortality in the nearshore Texas shrimp fishery (Table 7). Only the LGLM (IRDF=0.54) reduced real days fished in the Louisiana nearshore depth zone (Table 7). If the critical time period of high marine turtle abundance three weeks prior to and following the Texas closure is considered (Table 8), the LGLM and TER are very effective in reducing real days fished in the nearshore zone; IRDF=0.07 and IRDF=0.05, respectively.

Offshore real days fished increased more under the TER (IRDF=1.33) than for the LGLM (IRDF=1.23; Table 8). However, under the LGLM, TED equipped nets are not required in the offshore depth zone while under the TER, TEDs are required in the shrimp nets. As a result, sea turtle mortalities could be higher under the LGLM if all sea turtles species are considered. Only the TER reduces total real days fished for combined inshore, nearshore, and offshore zones in Texas (Table 7) as well as both regions combined (Table 6). However, if the nearshore is the main concern, only the LGLM reduces total real days fished in the nearshore zone in W. Louisiana.

## CONCLUSIONS

Because of its complexity, simple year to year comparisons cannot be made to determine the impacts of any single event in the shrimp fishery. The impact of regulations can be determined only through the use of a simulation model that holds all other influences constant. The GBFSM has been configured to estimate the change in fishing effort and vessel owner and crew rents expected under the CMR and four proposed management alternatives designed to reduce marine turtle bycatch in the Gulf of Mexico shrimp fishery.

A shrimp loss per tow assumption of 6.7% was used in evaluating four proposed turtle conservation management alternatives for the Gulf of Mexico shrimp fishery relative to the CMR. These regulations were the TSA/LGL developed by the Texas Shrimp Association, the LGLM developed by LGL Ecological Research Associates, Inc., and the TER and the R_TED developed by NMFS as interim measures to control sea turtle strandings.

Of the four proposed management alternatives, the LGLM and the TER achieve the stated objective of reducing sea turtle mortality in the nearshore Texas shrimp fishery (Table 6). Only the LGLM reduced effort (46 percent) in the Louisiana nearshore depth zone (Tables 7 and 8). If the critical time period of high marine turtle abundance three weeks prior to and following the Texas closure is considered (Table 8), these two proposed management alternatives are very effective in reducing real days fished in the nearshore zone in Texas. The TER was the only proposed management alternative that reduced total real days fished (3 percent) for the combined inshore, nearshore, and offshore zones (Table 6). Since TEDs are required in shrimp trawls in the TER, turtle mortalities in the offshore zone are expected to be lower even though real days fished

increase in the offshore zone. During the critical time period before and after the Texas Closure real days fished increase more than under the LGLM (Table 8) where TED equipped nets are not required.

The TER caused PVR relative to the CMR to remain unchanged in W. Louisiana and improved net benefits in Texas by $2.8 million (Table 3). The effect of the LGLM was much greater; PVR improved by $69.7 million. The R_TED had little perceivable impact on real days fished (Table 7) or on PVR (Table 8). The TSA/LGL did not reduce real days fished in the critical nearshore zone or overall, but did increase PVR to the shrimp harvesting sector by nearly $20 million. Marine turtle mortalities offshore would be expected to increase because of the overall increase in fishing effort (Table 7) and because TED-equipped nets are not required under the TSA/LGL.

Two caveats need to be discussed. First, only the TER decreased total real days fished below those of the CMR (Table 6). However, turtle strandings off Texas were at record levels in 1994 and 1995. This implies that under the TSA/LGL or R_TED, area closures off Texas and Louisiana could be expected. Under the TSA/LGL, the inshore and nearshore zones would be considered critical habitat. With an area closure, all activities that affect sea turtles would cease. Only the costs affecting the shrimp fishery are included in the analysis presented here; costs associated with closing other commercial and recreational fisheries or terminating other recreational activities, dredging, etc. are not included in this analysis.

Second, sea turtle bycatch in the Gulf of Mexico shrimp fishery results from the lack of clearly defined property rights for shrimp in the sea. Days fished will always be greater than is optimal for this fishery. That is, days fished are greater than the level at which the greatest number of shrimp are being harvested at the lowest cost to society.[8] Gear technology solutions do not address the common property nature of the fishery and therefore will not resolve the problem of sea turtle bycatch. However, gear modifications should lessen the impact of the shrimp fishery on sea turtle populations until a comprehensive solution can be found.

[8]Costs to society include the nonpecuniary benefits from sea turtle conservation as well as the costs associated with harvesting shrimp and the net present value of finfish bycatch and discards in the shrimp fishery.

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Table 1. Summary of proposed regulations.

| **Regulations** | **TSA/LGL[1]** | **LGLM[2]** | **First Level R_TED[3]** | **TER[4]** |
|---|---|---|---|---|
| Turtle Conservation Zone Limit | 6.2 sm | 6.2 sm | 10 nm | 10nm |
| TED Restrictions in TCZ | None | None | Top/Hard Only | Top/Hard Only |
| Net Restrictions in TCZ | 100 ft max | 100 ft max | None | 100 ft max during special 6 week period off Texas |
| TED Restrictions outside TCZ | No TED Required | No TED Required | TEDs Required | TEDs Required |
| Fishing Restrictions in TCZ | Night Fishing Prohibited | Night Fishing Prohibited | None | None |
| Vessel Size Restrictions in TCZ | None | >60' Prohibited All Times | None | >60' Prohibited during special 6 week period off Texas |
| Try Net Headrope Size Exempt from TED Requirements | <15 ft | <15 ft | <12 ft | <12 ft |
| Area for TCZ | Subareas 13-21 | Subareas 13-21 | Subareas 13-20 | Subareas 13-20 |
| Restrictions of Other Users | Yes | Yes | None | None |
| Regulation Time Limit | All Year | All Year | After Increased Strandings | All Year |

[1]TSA/LGL: TSA and LGL Proposed Management Alternative
[2]LGLM: Modified LGL Proposed Management Alternative
[3]R_TED: Restricted TEDs Proposed Management Alternative. If high strandings levels continue under the first level then TCZ will be closed for 30 days to shrimping -- presently in effect as an emergency regulation.
[4]TER: Temporary Effort Reduction Proposed Management Alternative

Table 2. Generalized Bioeconomic Fishery Simulation Model (GBFSM) Constraints.

| **Regulations** | **TSA/LGL** | **LGLM** | **First Level R_TED*** | **TER** |
|---|---|---|---|---|
| Turtle Conservation Zone Limit | 5 fm LA; 10 fm TX | 5 fm LA; 10 fm TX | 5 fm LA; 10 fm TX | 5 fm LA; 10 fm TX |
| TED Restrictions in TCZ | NA | NA | 10% cost increase in TEDs per year | 10% cost increase in TEDs per year |
| Net Restrictions in TCZ | Vessels moved offshore | Vessels moved offshore | NA | Vessels moved offshore during 6 week period in Texas |
| TED Restrictions outside TCZ | TED costs, Vessel downtime, Shrimp Loss Removed | TED costs, Vessel downtime, Shrimp Loss Removed | NA | NA |
| Fishing Restrictions in TCZ | Not Possible with Model | Not Possible with Model | NA | NA |
| Vessel Size Restrictions in TCZ | Vessels moved offshore | Vessels moved offshore | NA | Vessels moved offshore during 6 week period in Texas |
| Try Net Headrope Size Exempt from TED Requirements | Not Possible with Model | Not Possible with Model | Not Possible with Model | Not Possible with Model |
| Area for TCZ | Only 2 Areas Possible | Only 2 Areas Possible | Only 2 Areas Possible | Only 2 Areas Possible |
| Restrictions of Other Users | Not Possible with Model | Not Possible with Model | Not Possible with Model | Not Possible with Model |
| Regulation Time Limit | Each Time Step | Each Time Step | Once per Year | Each Time Step |

[1]TSA/LGL: TSA and LGL Proposed Management Alternative

[2]LGLM: Modified LGL Proposed Management Alternative

[3]R_TED: Restricted TEDs Proposed Management Alternative. If high strandings levels continue under the first level then TCZ will be closed for 30 days to shrimping -- presently in effect as an emergency regulation.

[4]TER: Temporary Effort Reduction Proposed Management Alternative

Table 3. Differences in net present value of rents over 25-year simulation period ($ 1000) for changes from the current management regulations (CMR[1]) to proposed management alternatives for vessel owner and crew.

| Region | TSA/LGL[2] | LGLM[3] | R_TED[4] | TER[5] |
|---|---|---|---|---|
| W. Louisiana | | | | |
| Vessel class 1 | 36 | 5,225 | 0 | 0 |
| Vessel class 2 | -1,199 | 73,867 | 2 | 0 |
| Vessel class 3 | -236 | 14,958 | -2 | 0 |
| Vessel class 4 | 768 | 26,113 | 9 | 0 |
| Vessel class 5 | 11,165 | -56,045 | -13 | 0 |
| Total | 10,534 | 64,118 | -4 | 0 |
| | | | | |
| Texas | | | | |
| Vessel class 1 | 4 | 725 | 0 | 465 |
| Vessel class 2 | -99 | 2,102 | 1 | 816 |
| Vessel class 3 | 243 | 2,861 | -1 | 764 |
| Vessel class 4 | 501 | -1,558 | 8 | -697 |
| Vessel class 5 | 8,335 | 1,500 | 0 | 1,418 |
| Total | 8,984 | 5,630 | 8 | 2,766 |
| | | | | |
| Grand Total | 19,518 | 69,748 | 4 | 2,766 |

[1]CMR: Current Management Regulations
[2]TSA/LGL: TSA and LGL Proposed Management Alternative
[3]LGLM: Modified LGL Proposed Management Alternative
[4]R_TED: Restricted TEDs Proposed Management Alternative -- presently in effect as an emergency regulation.
[5]TER: Temporary Effort Reduction Proposed Management Alternative

Table 4. Differences in net present value of rents over 25-year simulation period ($ 1000) for changes from the current management regulations (CMR[1]) to proposed management alternatives for vessel owner.

| Region | TSA/LGL[2] | LGLM[3] | R_TED[4] | TER[5] |
|---|---|---|---|---|
| W. Louisiana | | | | |
| Vessel class 1 | 33 | 4,302 | -1 | 0 |
| Vessel class 2 | -919 | 59,007 | 3 | 0 |
| Vessel class 3 | -174 | 11,768 | -2 | 0 |
| Vessel class 4 | 694 | 26,066 | 10 | 0 |
| Vessel class 5 | 9,671 | -40,144 | -10 | 0 |
| Total | 9,305 | 60,999 | 0 | 0 |
| Texas | | | | |
| Vessel class 1 | 6 | 588 | 0 | 377 |
| Vessel class 2 | -71 | 1,625 | 2 | 641 |
| Vessel class 3 | 198 | 2,383 | 0 | 593 |
| Vessel class 4 | 412 | -1,333 | 8 | -587 |
| Vessel class 5 | 9,463 | -4,745 | 0 | -1,563 |
| Total | 10,008 | -1,482 | 10 | -539 |
| Grand Total | 19,313 | 59,517 | 10 | -539 |

[1]CMR: Current Management Regulations
[2]TSA/LGL: TSA and LGL Proposed Management Alternative
[3]LGLM: Modified LGL Proposed Management Alternative
[4]R_TED: Restricted TEDs Proposed Management Alternative -- presently in effect as an emergency regulation.
[5]TER: Temporary Effort Reduction Proposed Management Alternative

Table 5. Differences in net present value of rents over 25-year simulation period ($ 1000) for changes from the current management regulations (CMR[1]) to proposed management alternatives for vessel crew.

| Region | TSA/LGL[2] | LGLM[3] | R_TED[4] | TER[5] |
|---|---|---|---|---|
| W. Louisiana | | | | |
| Vessel class 1 | 1 | 922 | -1 | 0 |
| Vessel class 2 | -280 | 14,859 | -1 | 0 |
| Vessel class 3 | -62 | 3,190 | 0 | 0 |
| Vessel class 4 | 74 | 46 | -1 | 0 |
| Vessel class 5 | 1,494 | -15,901 | -3 | 0 |
| Total | 1,227 | 3,116 | -6 | 0 |
| Texas | | | | |
| Vessel class 1 | -2 | 137 | 0 | 88 |
| Vessel class 2 | -29 | 477 | 0 | 176 |
| Vessel class 3 | 45 | 478 | 0 | 171 |
| Vessel class 4 | 89 | -226 | 0 | -110 |
| Vessel class 5 | -1,128 | 6,245 | 0 | 2,980 |
| Total | -1,025 | 7,111 | 0 | 3,305 |
| Grand Total | 202 | 10,227 | -6 | 3,305 |

[1]CMR: Current Management Regulations
[2]TSA/LGL: TSA and LGL Proposed Management Alternative
[3]LGLM: Modified LGL Proposed Management Alternative
[4]R_TED: Restricted TEDs Proposed Management Alternative -- presently in effect as an emergency regulation.
[5]TER: Temporary Effort Reduction Proposed Management Alternative

Table 6. Ratio of real days fished[1] for the proposed management alternatives to the current management regulations (CMR[2]).

| Region | TSA/LGL[3] | LGLM[4] | R_TED[5] | TER[6] |
|---|---|---|---|---|
| W. Louisiana | | | | |
| Vessel class 1 | 1.04 | 1.14 | 1.00 | 1.00 |
| Vessel class 2 | 0.98 | 1.45 | 1.00 | 1.00 |
| Vessel class 3 | 0.90 | 1.66 | 1.00 | 1.00 |
| Vessel class 4 | 1.11 | 1.78 | 1.00 | 1.00 |
| Vessel class 5 | 1.06 | 0.82 | 1.00 | 1.00 |
| Total | 1.03 | 1.14 | 1.00 | 1.00 |
| Texas | | | | |
| Vessel class 1 | 1.00 | 1.12 | 1.00 | 1.02 |
| Vessel class 2 | 0.99 | 1.15 | 1.00 | 1.02 |
| Vessel class 3 | 1.02 | 2.40 | 1.00 | 1.00 |
| Vessel class 4 | 1.03 | 1.08 | 1.00 | 1.01 |
| Vessel class 5 | 1.10 | 0.94 | 1.00 | 0.95 |
| Total | 1.07 | 1.00 | 1.00 | 0.97 |
| Both States | 1.05 | 1.09 | 1.00 | 0.99 |

[1]Calculated as the sum of real days fished over the 25-year period for the proposed management alternatives divided by the sum of real days fished over the 25-year period for the CMR.

[2]CMR: Current Management Regulations

[3]TSA/LGL: TSA and LGL Proposed Management Alternative

[4]LGLM: Modified LGL Proposed Management Alternative

[5]R_TED: Restricted TEDs Proposed Management Alternative -- presently in effect as an emergency regulation.

[6]TER: Temporary Effort Reduction Proposed Management Alternative

Table 7. Ratio of real days fished[1] for the proposed management alternatives to the current management regulations (CMR[2]).

| Zone | TSA/LGL[3] | LGLM[4] | R_TED[5] | TER[6] |
|---|---|---|---|---|
| W. Louisiana | | | | |
| Inshore | 0.99 | 1.25 | 1.00 | 1.00 |
| Nearshore | 1.03 | 0.54 | 1.00 | 1.00 |
| Offshore | 1.07 | 1.60 | 1.00 | 1.00 |
| All Zones | 1.03 | 1.14 | 1.00 | 1.00 |
| Texas | | | | |
| Inshore | 1.00 | 1.03 | 1.00 | 1.01 |
| Nearshore | 1.06 | 0.10 | 1.00 | 0.68 |
| Offshore | 1.11 | 1.23 | 1.00 | 1.02 |
| All Zones | 1.07 | 1.00 | 1.00 | 0.97 |

[1]Calculated as the sum of real days fished over the 25-year period for the proposed management alternatives divided by the sum of real days fished over the 25-year period for the CMR.

[2]CMR: Current Management Regulations

[3]TSA/LGL: TSA and LGL Proposed Management Alternative

[4]LGLM: Modified LGL Proposed Management Alternative

[5]R_TED: Restricted TEDs Proposed Management Alternative -- presently in effect as an emergency regulation.

[6]TER: Temporary Effort Reduction Proposed Management Alternative

Table 8. Ratio of real days fished[1] for the proposed management alternatives to the current management regulations (CMR[2]) during the period from the last week in April through the first week in August.

| Zone | TSA/LGL[3] | LGLM[4] | R_TED[5] | TER[6] |
|---|---|---|---|---|
| W. Louisiana | | | | |
| Inshore | 0.99 | 1.18 | 1.00 | 1.00 |
| Nearshore | 1.02 | 0.67 | 1.00 | 1.00 |
| Offshore | 1.07 | 1.66 | 1.00 | 1.00 |
| All Zones | 1.02 | 1.15 | 1.00 | 1.00 |
| Texas | | | | |
| Inshore | 1.00 | 1.12 | 1.00 | 1.00 |
| Nearshore | 1.06 | 0.07 | 1.00 | 0.05 |
| Offshore | 1.11 | 1.23 | 1.00 | 1.33 |
| All Zones | 1.05 | 0.99 | 1.00 | 0.98 |

[1]Calculated as the sum of real days fished over the 25-year period for the proposed management alternatives divided by the sum of real days fished over the 25-year period for the CMR.

[2]CMR: Current Management Regulations

[3]TSA/LGL: TSA and LGL Proposed Management Alternative

[4]LGLM: Modified LGL Proposed Management Alternative

[5]R_TED: Restricted TEDs Proposed Management Alternative -- presently in effect as an emergency regulation.

[6]TER: Temporary Effort Reduction Proposed Management Alternative

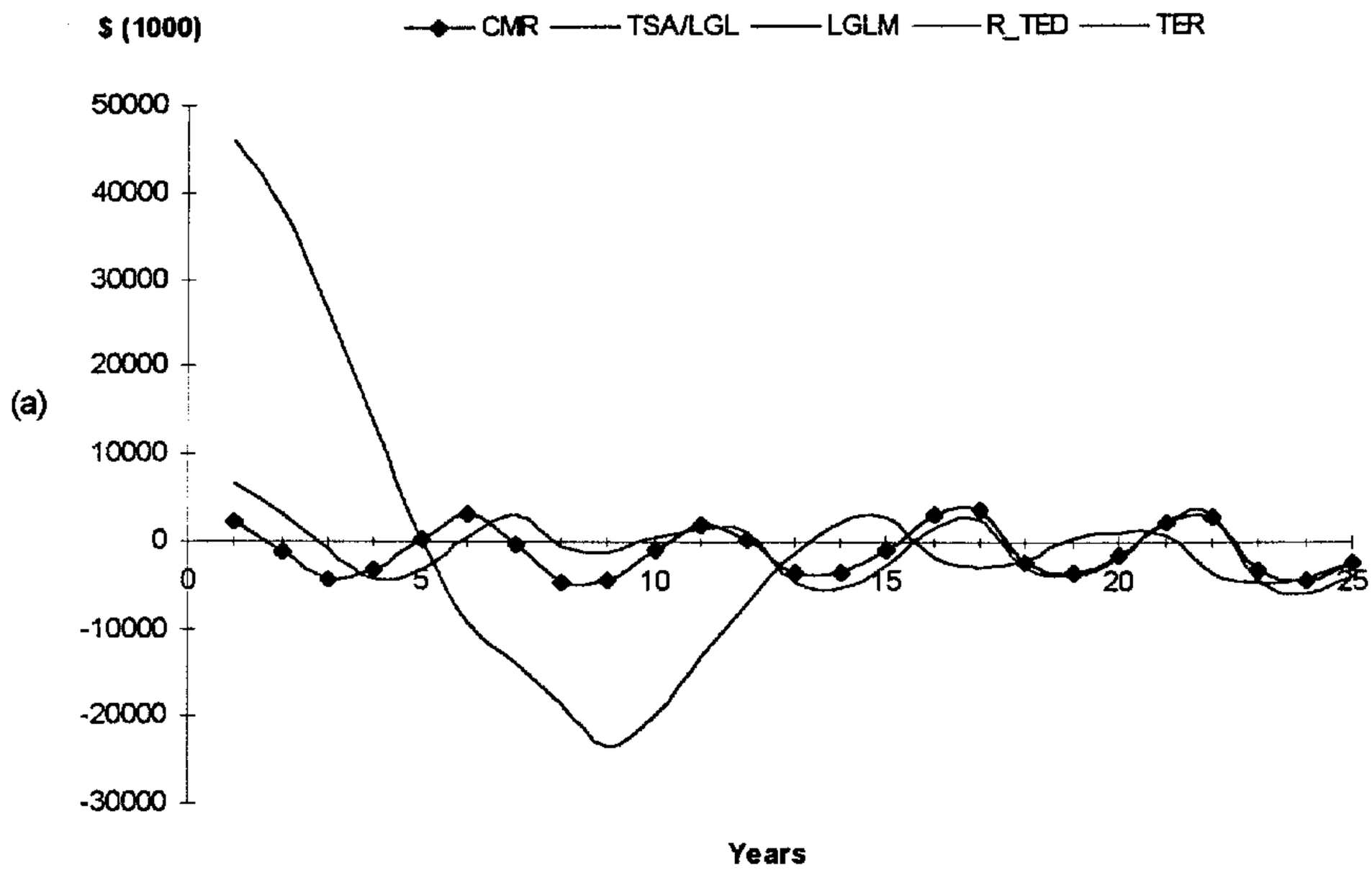



Figure 1. Vessel owner's rent (a) and real days fished (b) for all vessel classes operating in W. Louisiana waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)

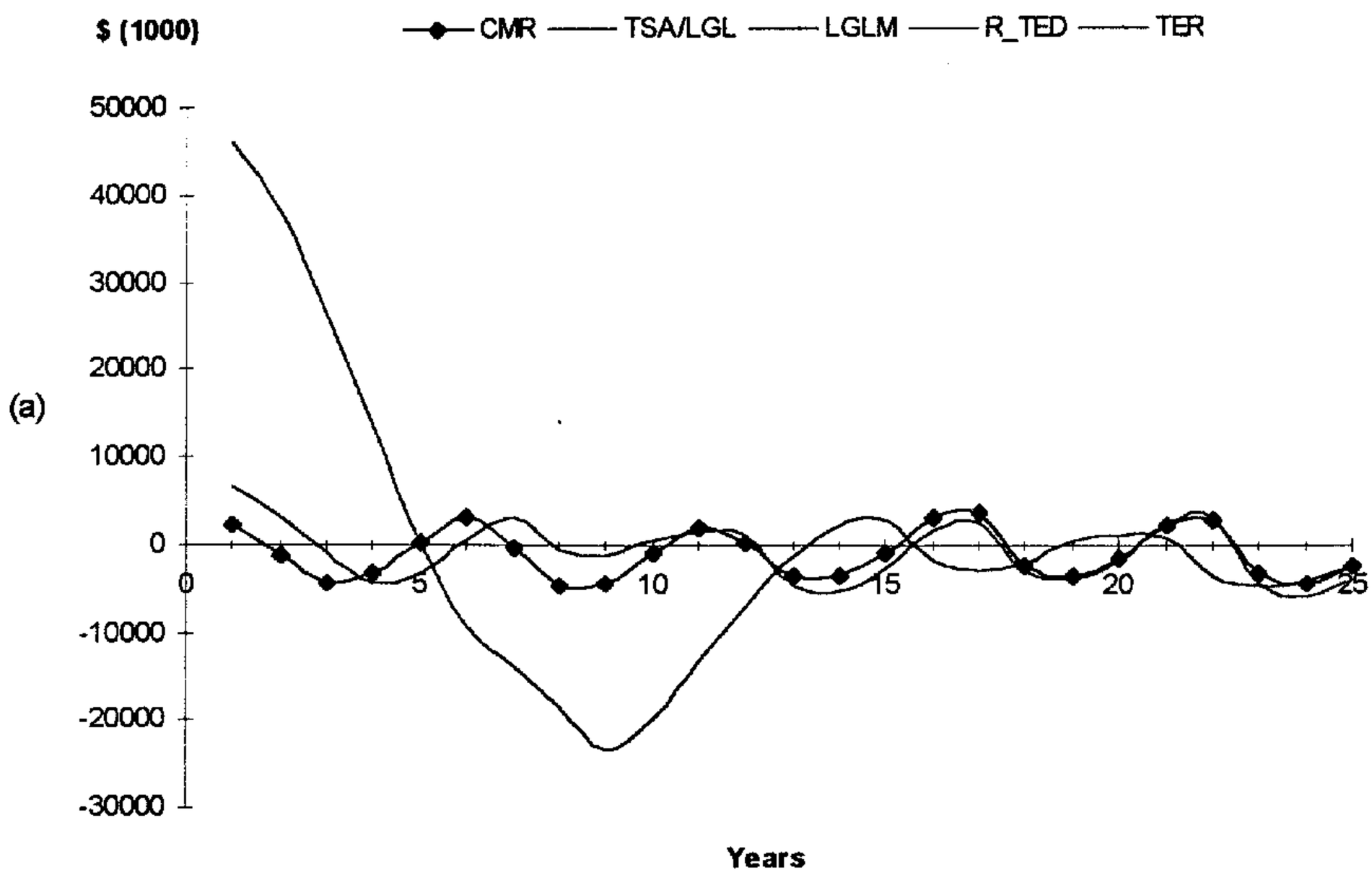
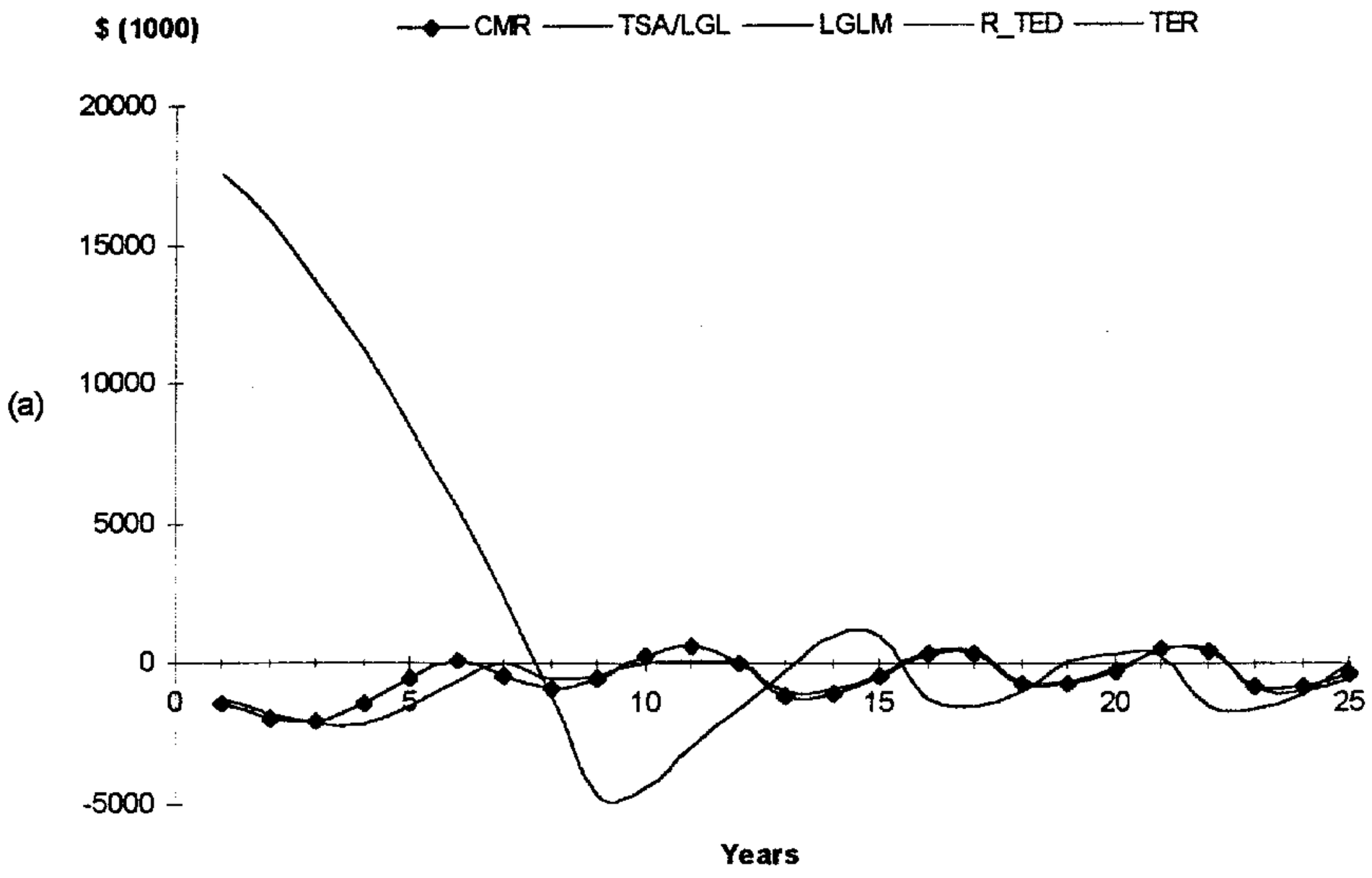
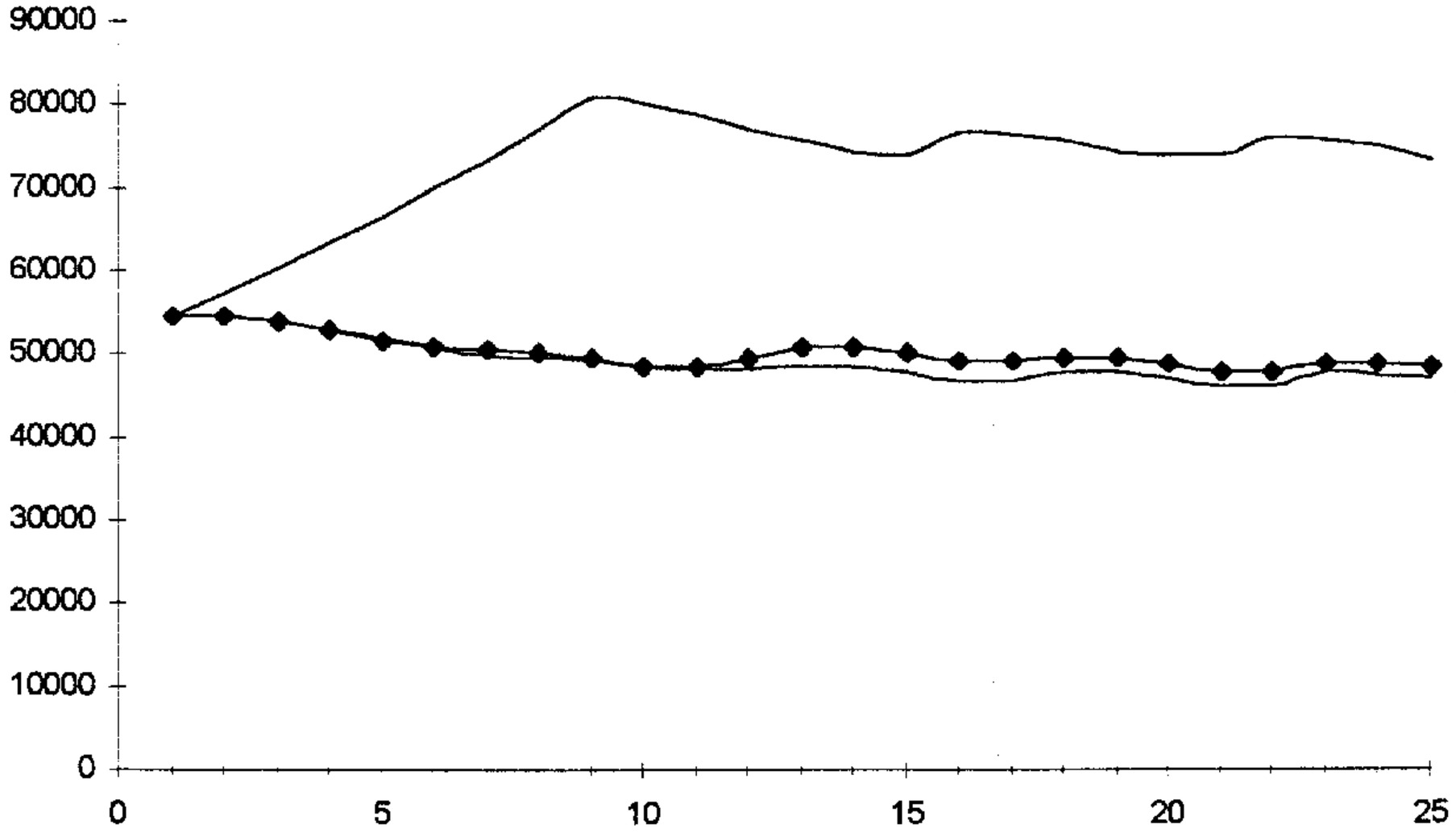



Figure 2. Vessel owner's rent (a) and real days fished (b) for vessel class 1 (length $\leq 40$ ft) operating in W. Louisiana waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)




(a)

**Real Days Fished**




(b)

Figure 3. Vessel owner's rent (a) and real days fished (b) for vessel class 2 ($40 > \text{length} \leq 55$ ft w/headrope $< 100$ ft) operating in W. Louisiana waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)

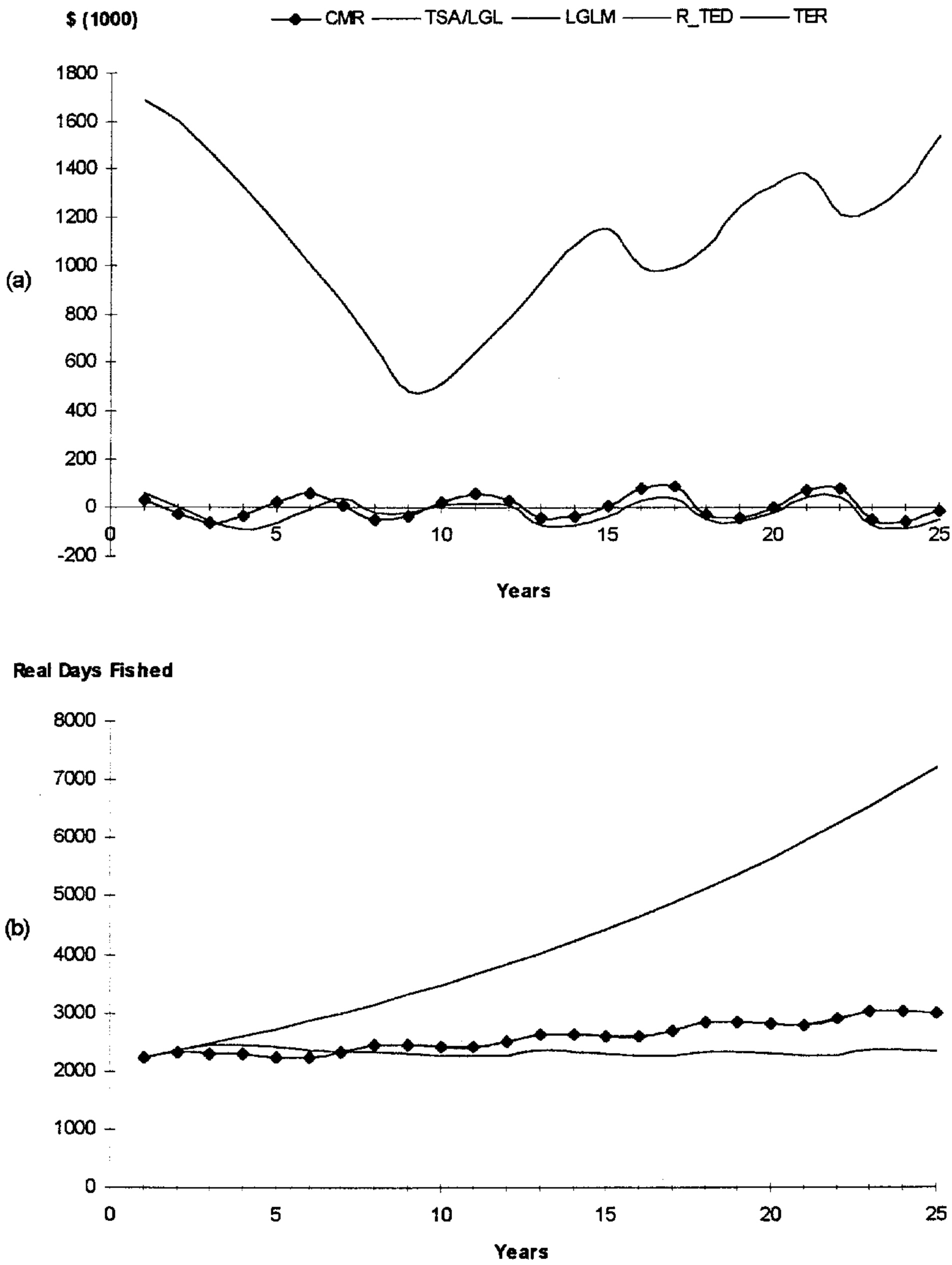
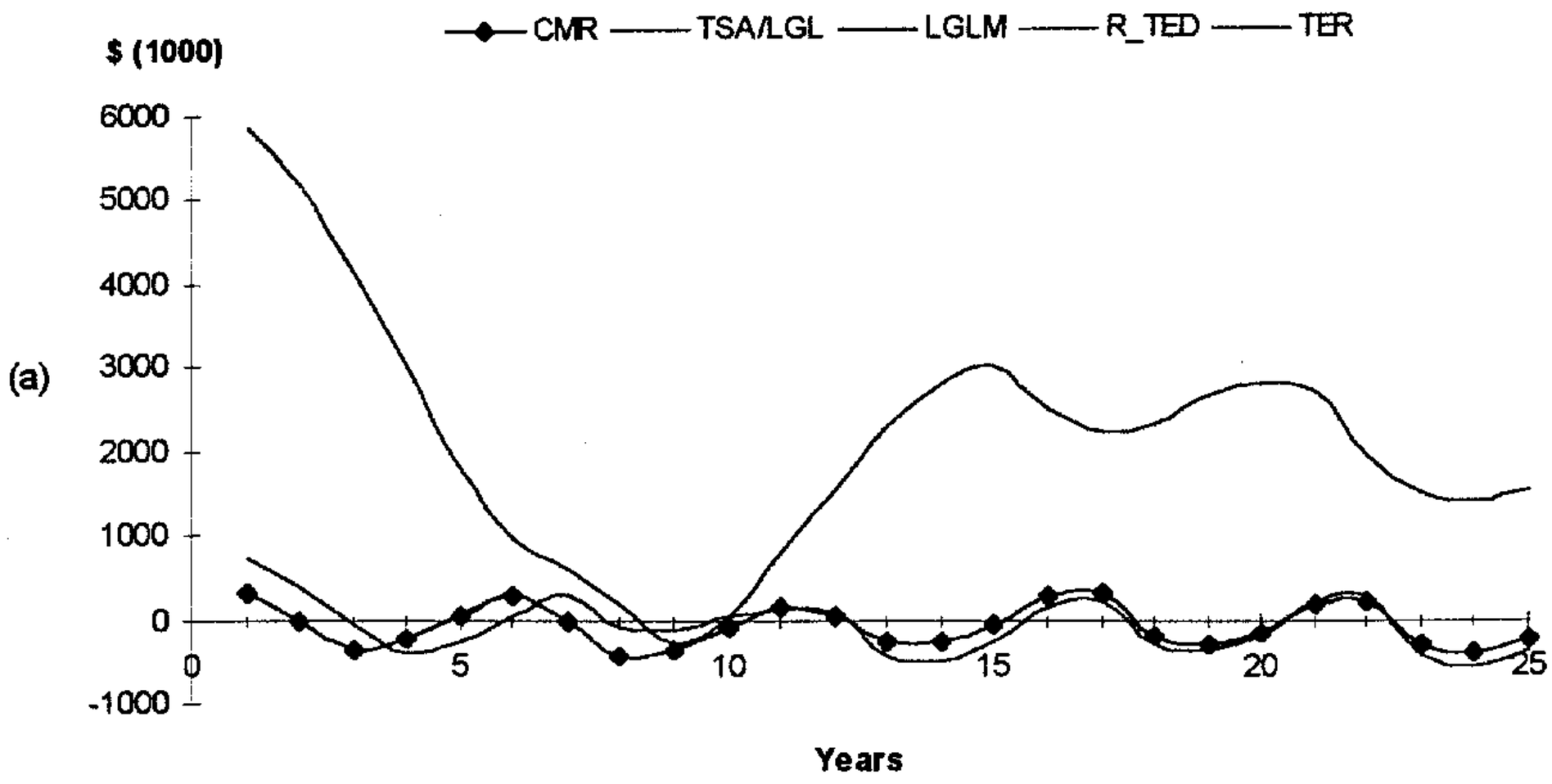
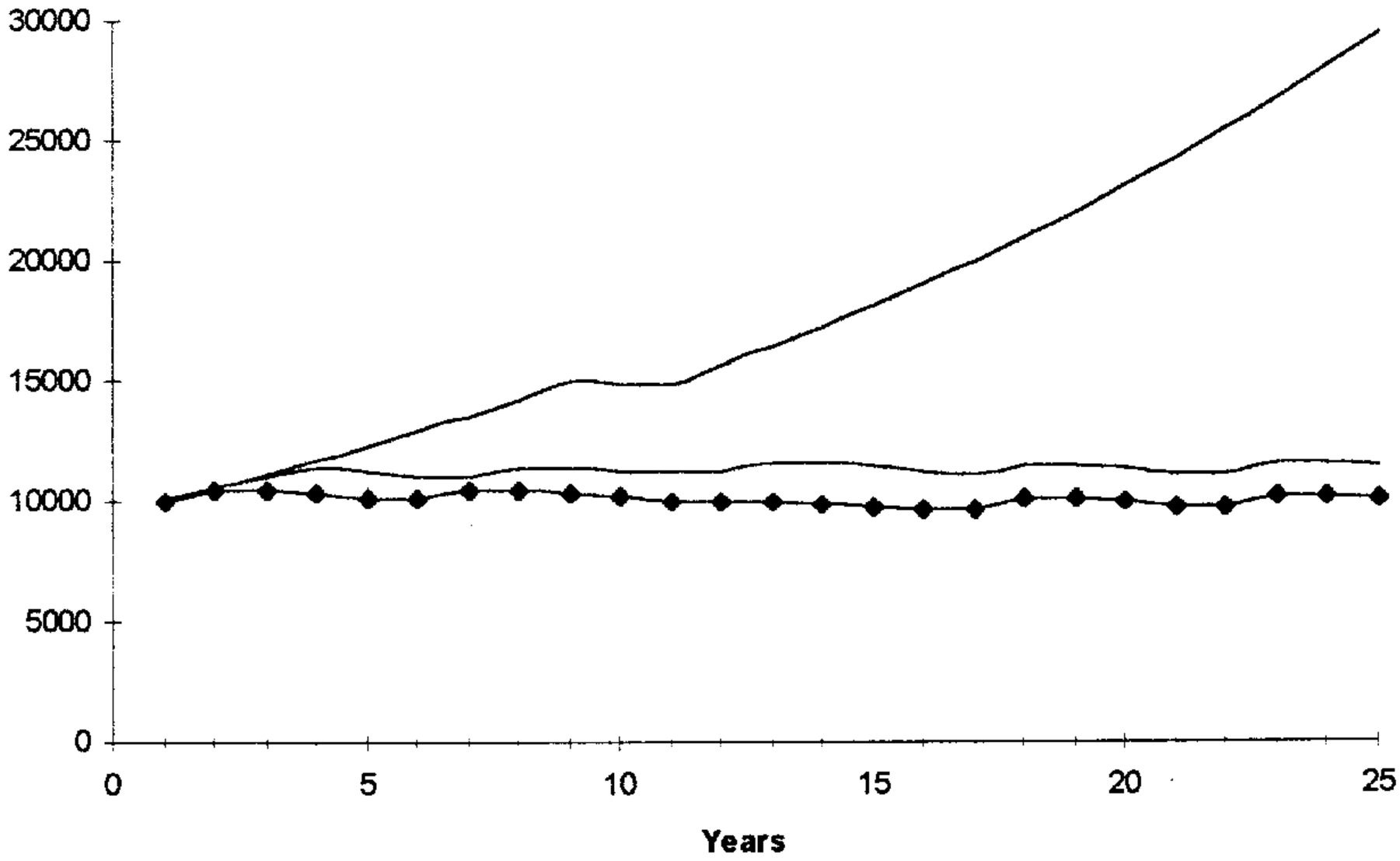



Figure 4. Vessel owner's rent (a) and real days fished (b) for vessel class 3 (40 > length ≤ 55 ft w/headrope > 100 ft) operating in W. Louisiana waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)




(a)

**Real Days Fished**




(b)

Figure 5. Vessel owner's rent (a) and real days fished (b) for vessel class 4 (length > 55 ft w/headrope < 100 ft) operating in W. Louisiana waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)

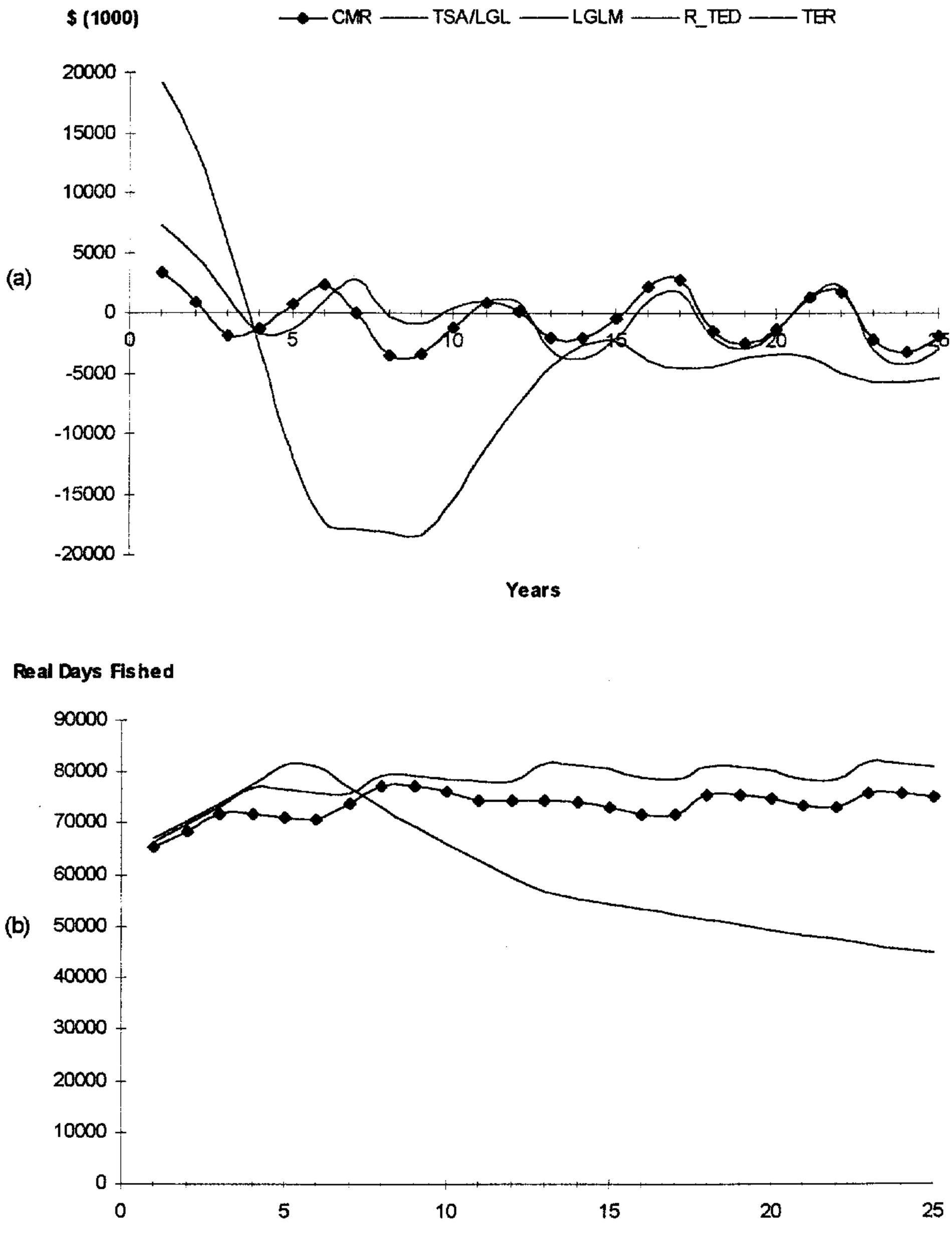



Figure 6. Vessel owner's rent (a) and real days fished (b) for vessel class 5 (length > 55 ft w/headrope > 100 ft) operating in W. Louisiana waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)

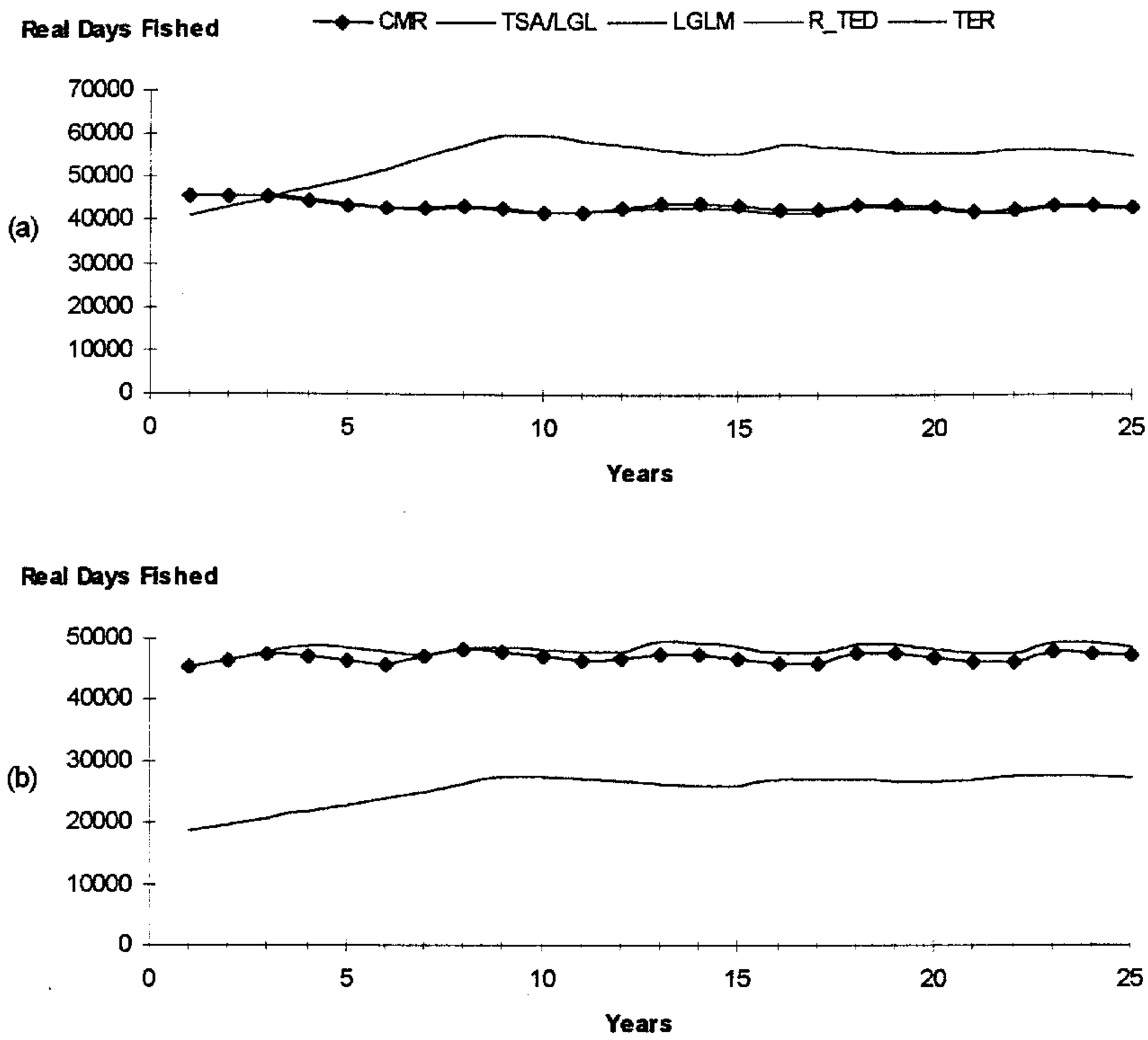



Figure 7. Real days fished in the (a) inshore, (b) nearshore and (c) offshore waters W. Louisiana for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)

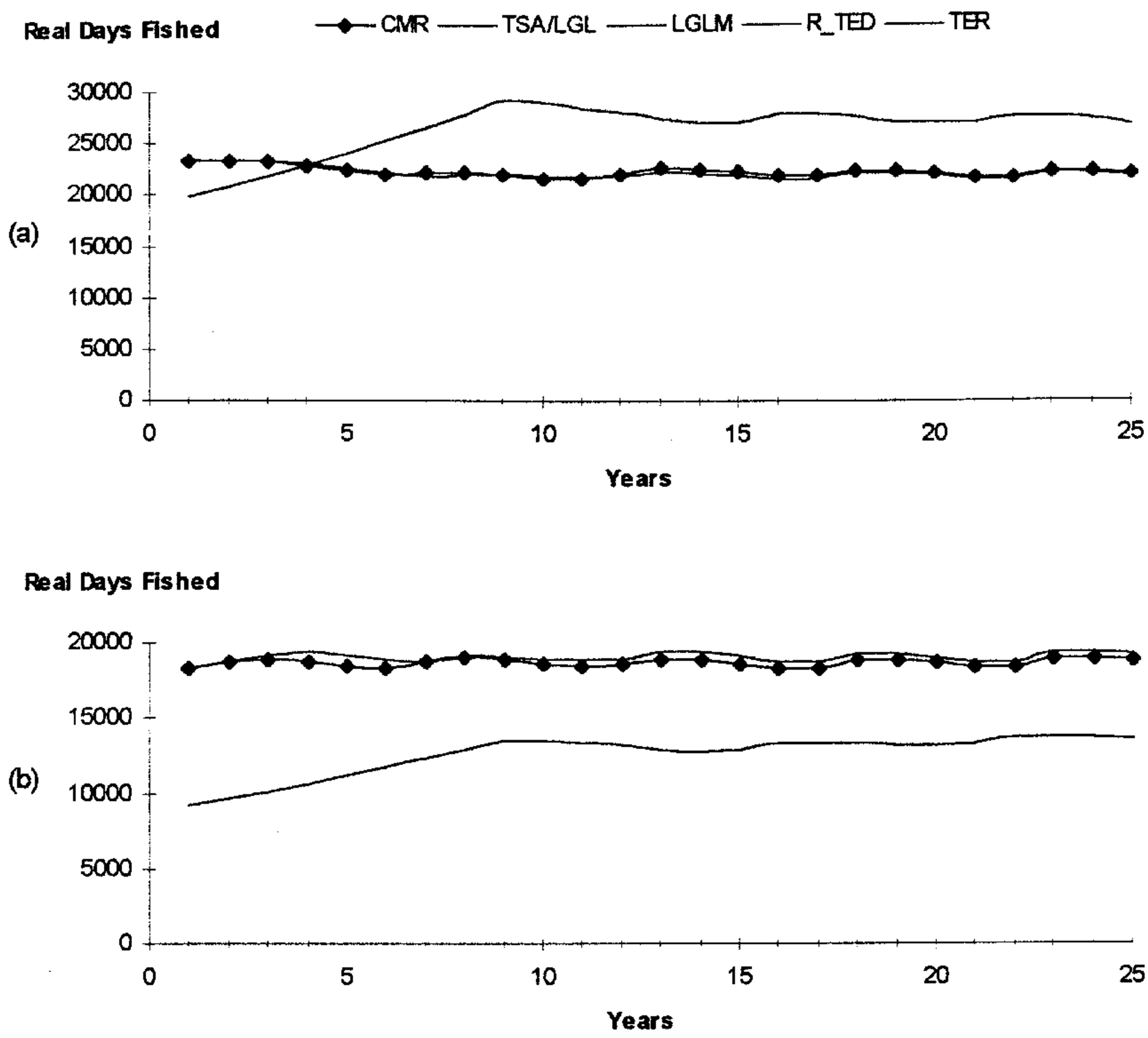
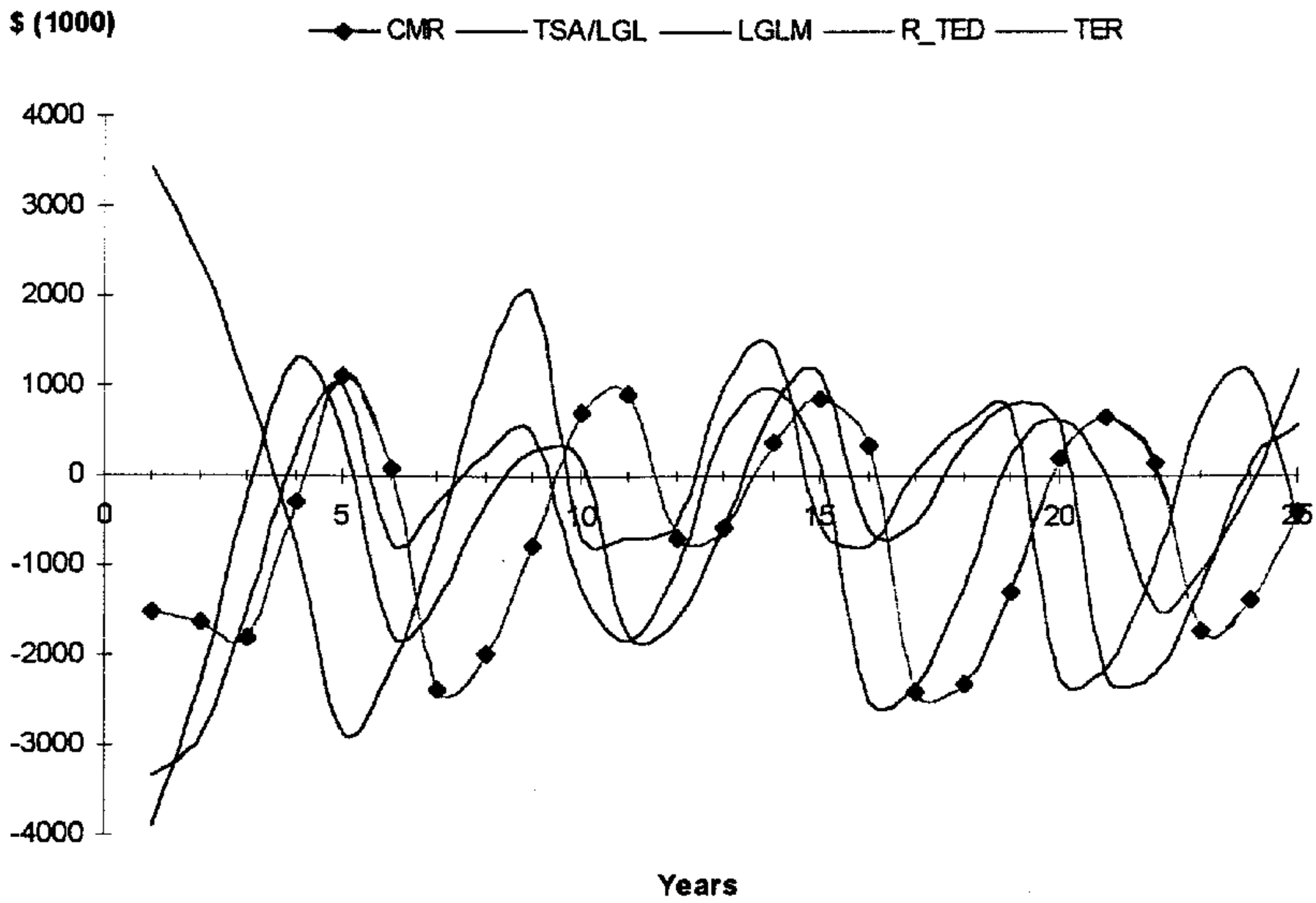



Figure 8. Real days fished during the last week in April through the first week in August in the (a) inshore, (b) nearshore and (c) offshore waters W. Louisiana for existing current management regulation (CMR) versus four proposed management alternatives. (CMR, R_TED, and TER appears as a single line but are actually three lines.)




(b)

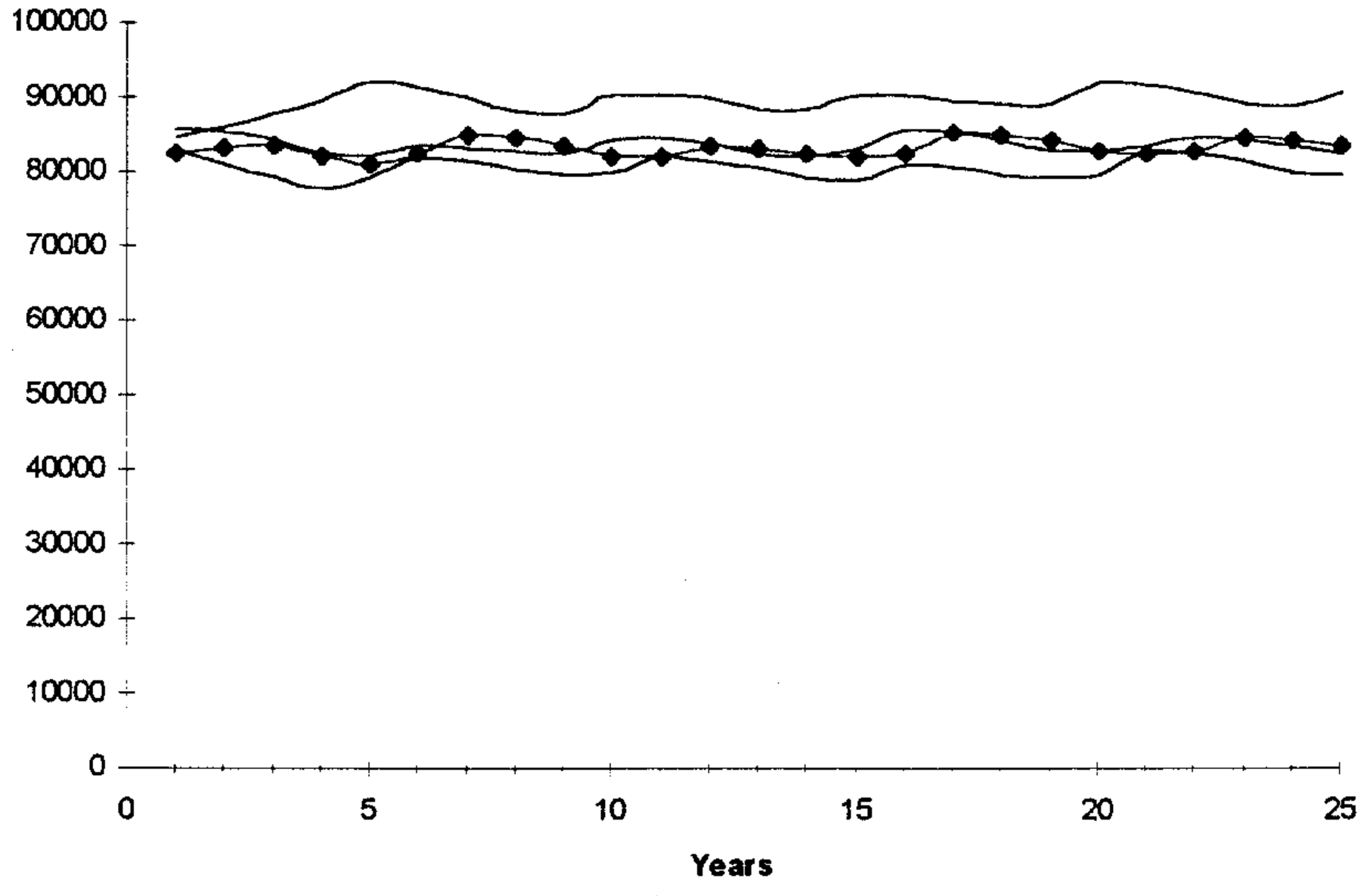



Figure 9. Vessel owner's rent (a) and real days fished (b) for all vessel classes operating in Texas waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)

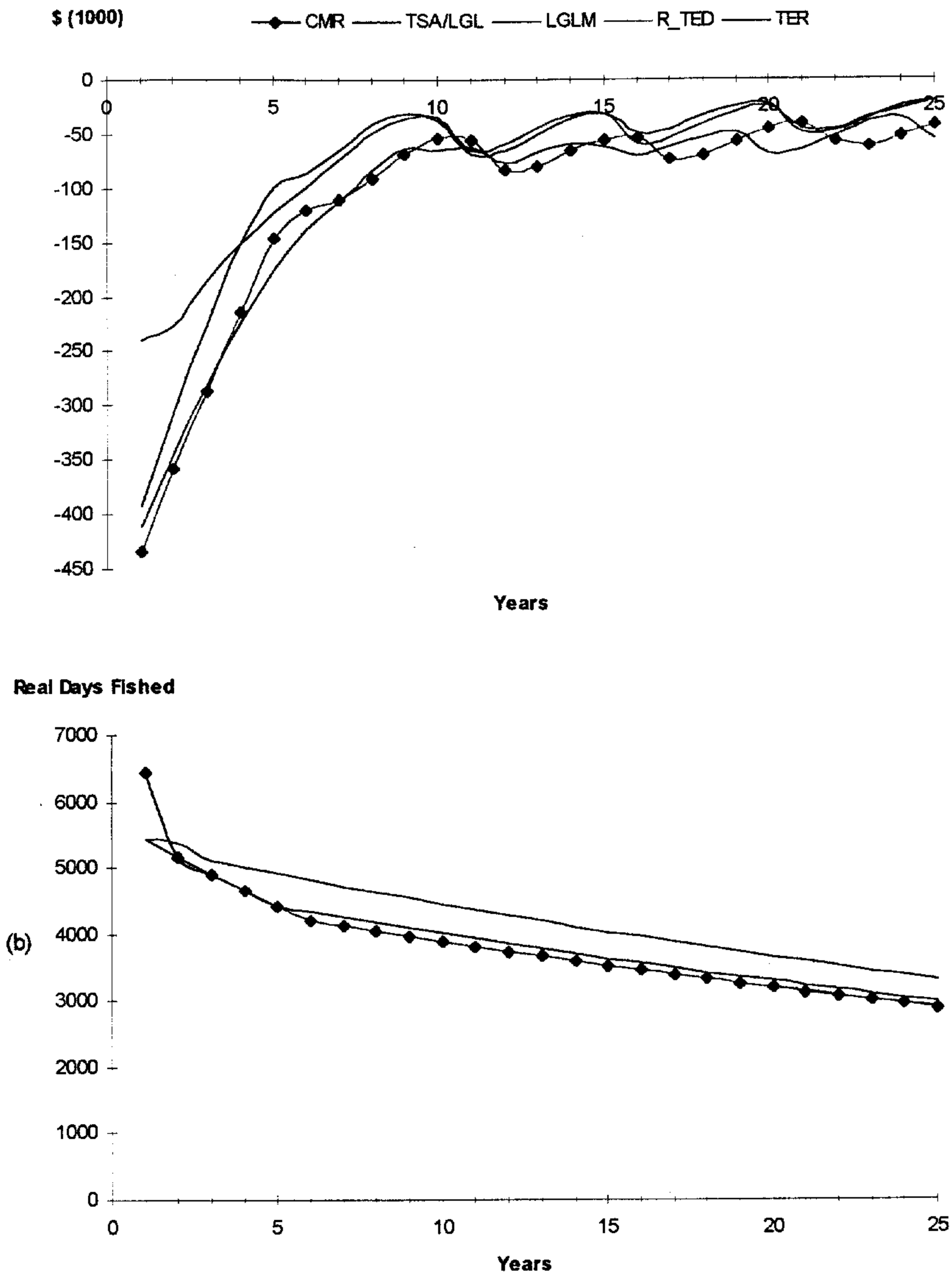



Figure 10. Vessel owner's rent (a) and real days fished (b) for vessel class 1 (length $\leq 40$ ft) operating in Texas waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)

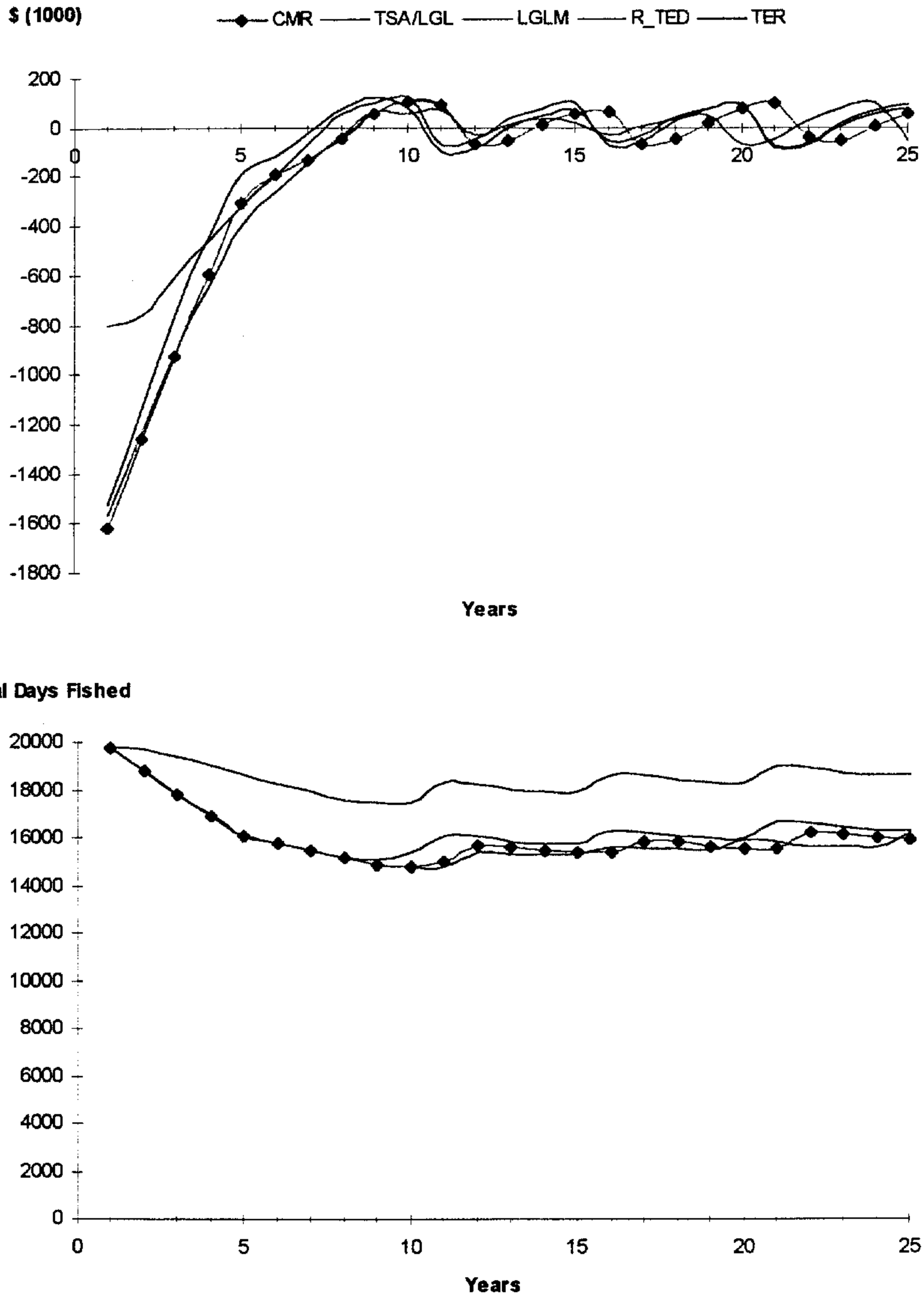
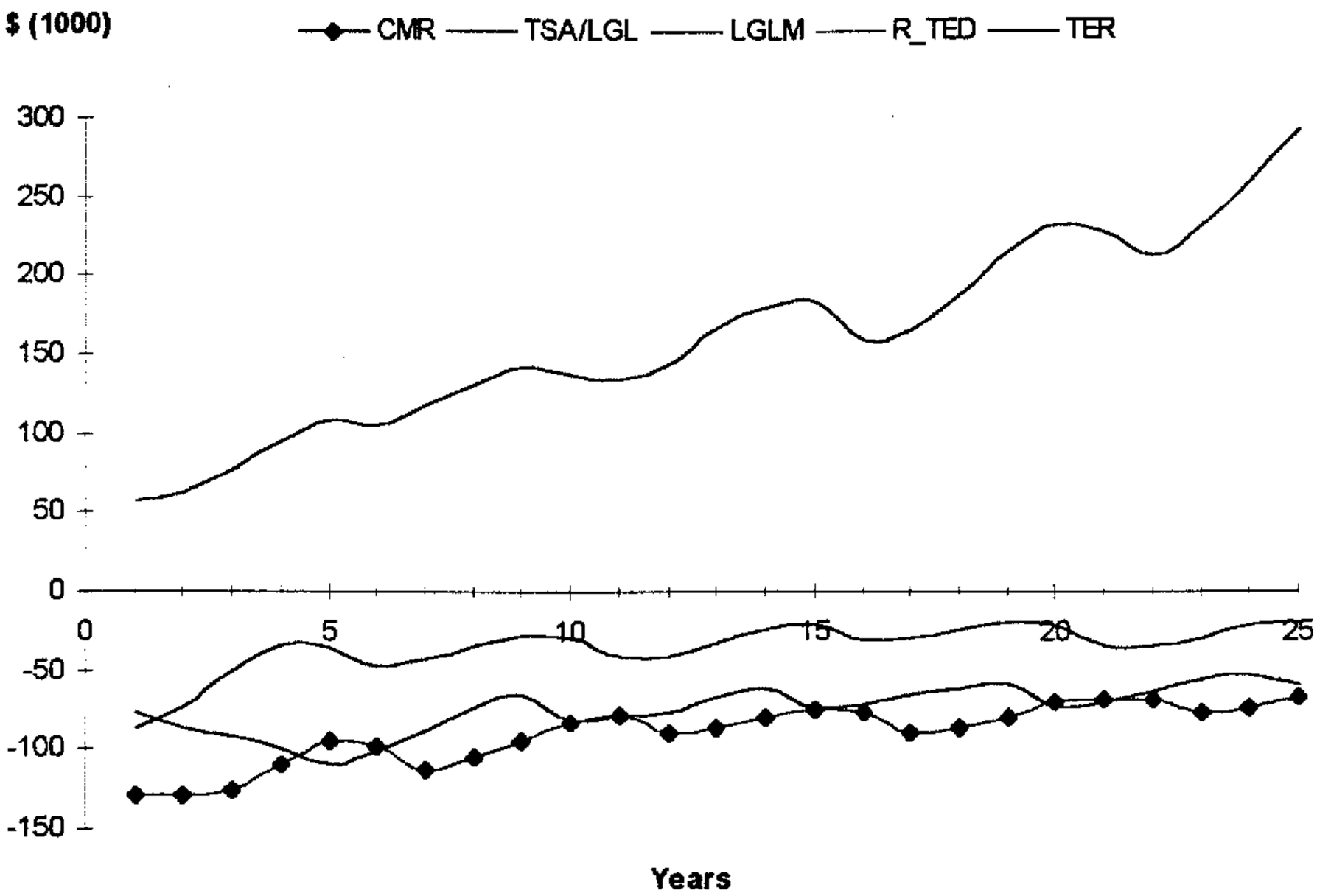



Figure 11. Vessel owner's rent (a) and real days fished (b) for vessel class 2 ($40 > \text{length} \leq 55$ ft w/headrope $< 100$ ft) operating in Texas waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)



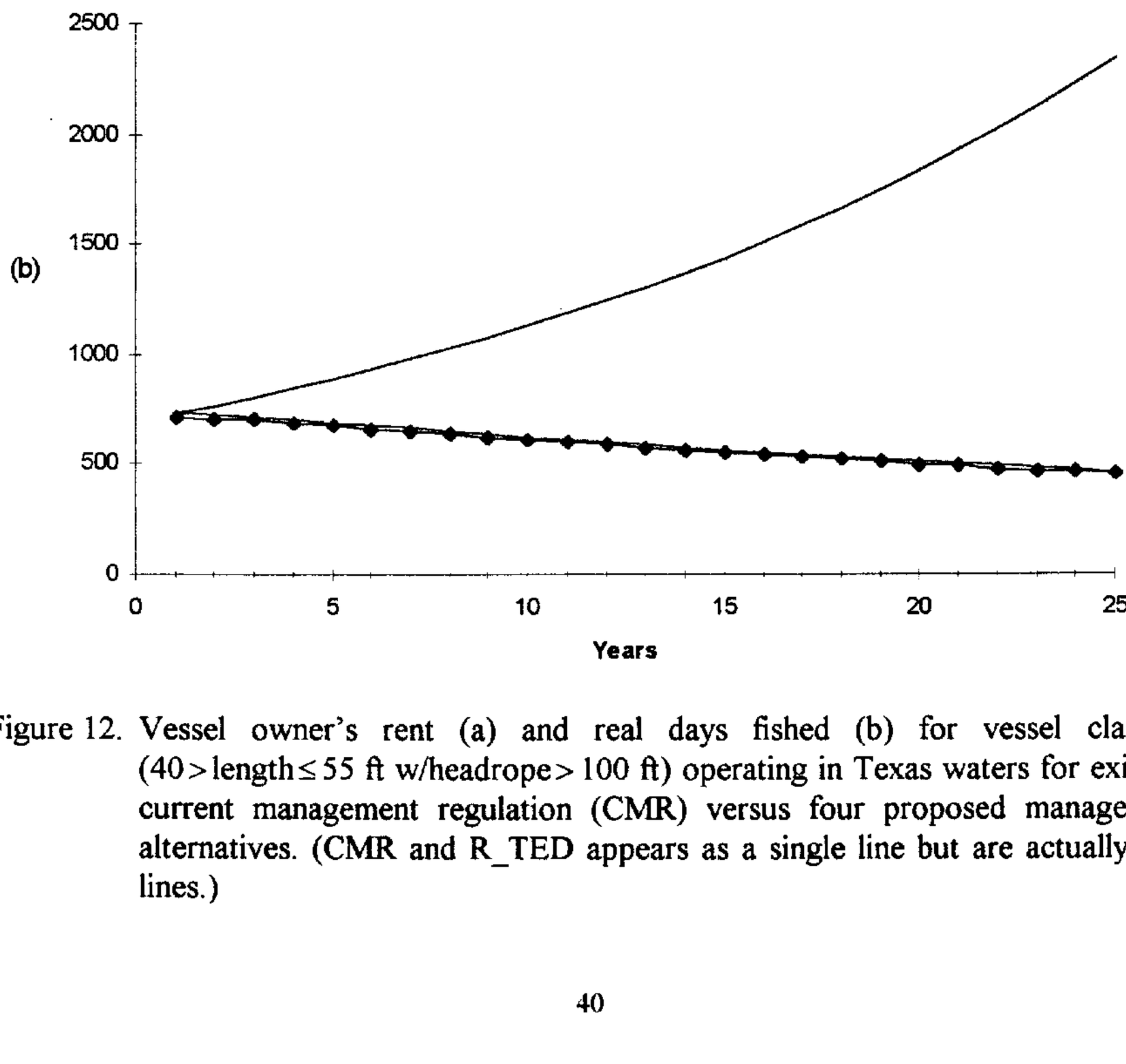




Figure 12. Vessel owner's rent (a) and real days fished (b) for vessel class 3 ($40 > \text{length} \leq 55$ ft w/headrope $> 100$ ft) operating in Texas waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)

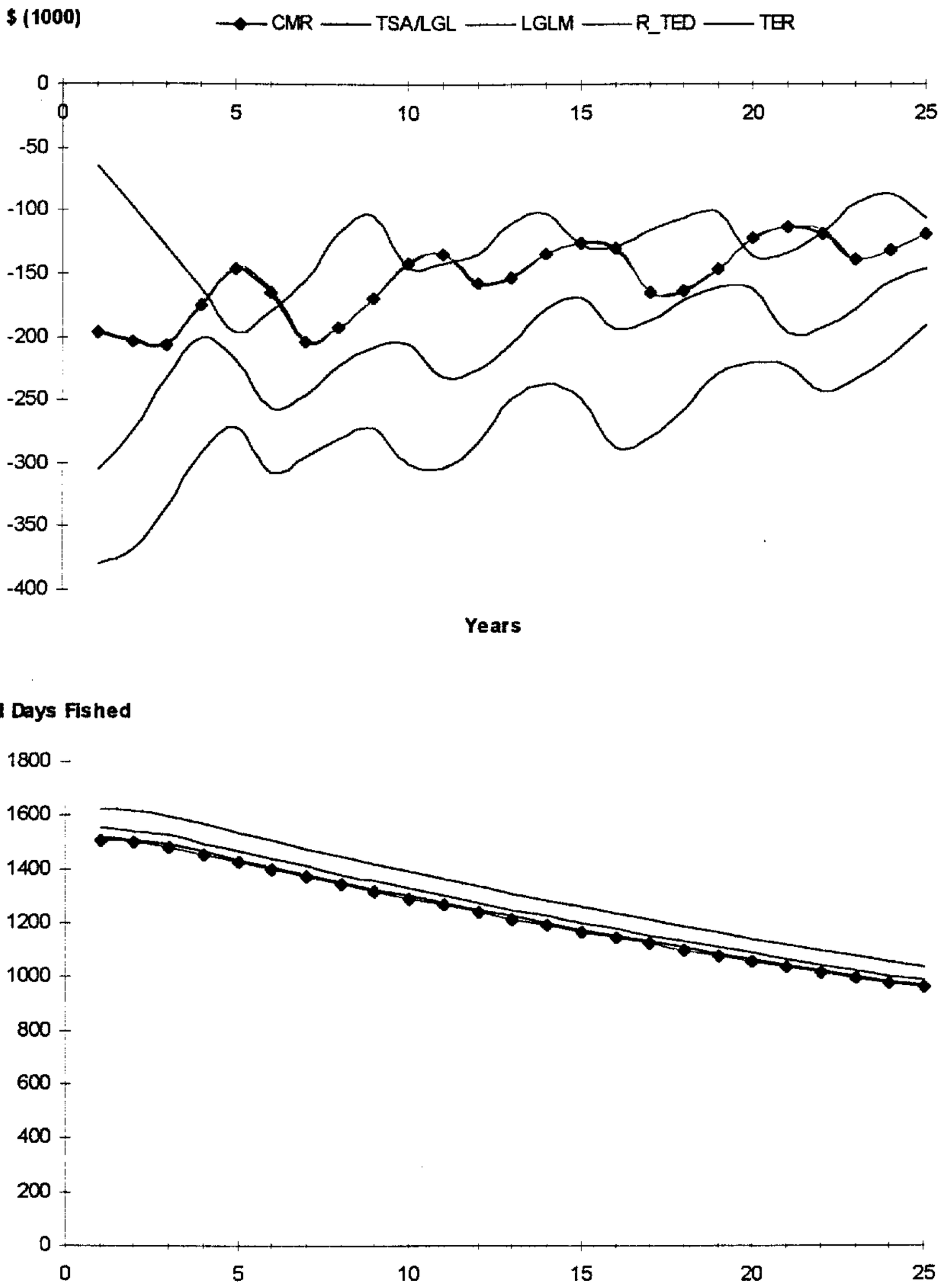
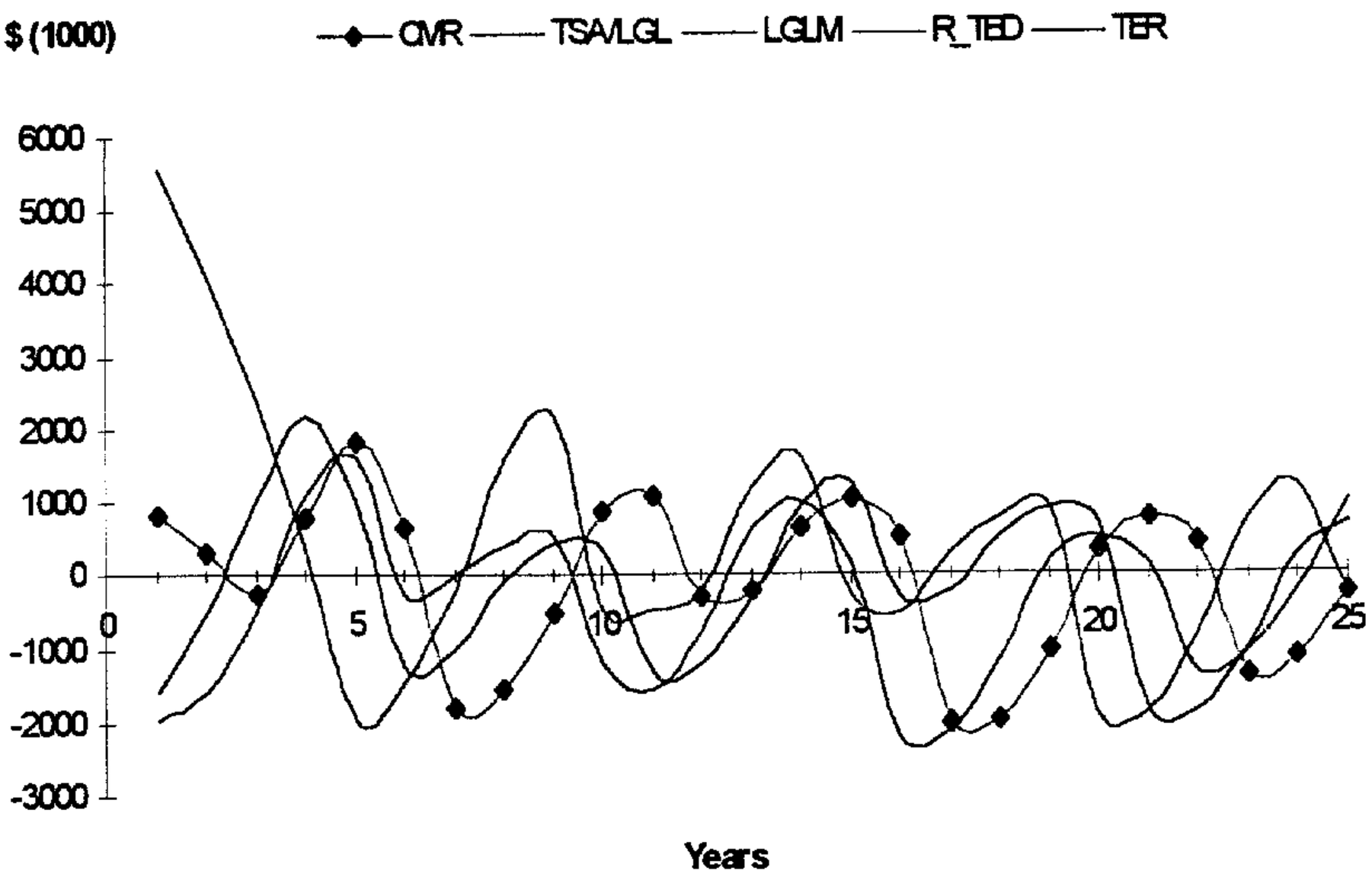



Figure 13. Vessel owner's rent (a) and real days fished (b) for vessel class 4 (length > 55 ft w/headrope < 100 ft)) operating in Texas waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)



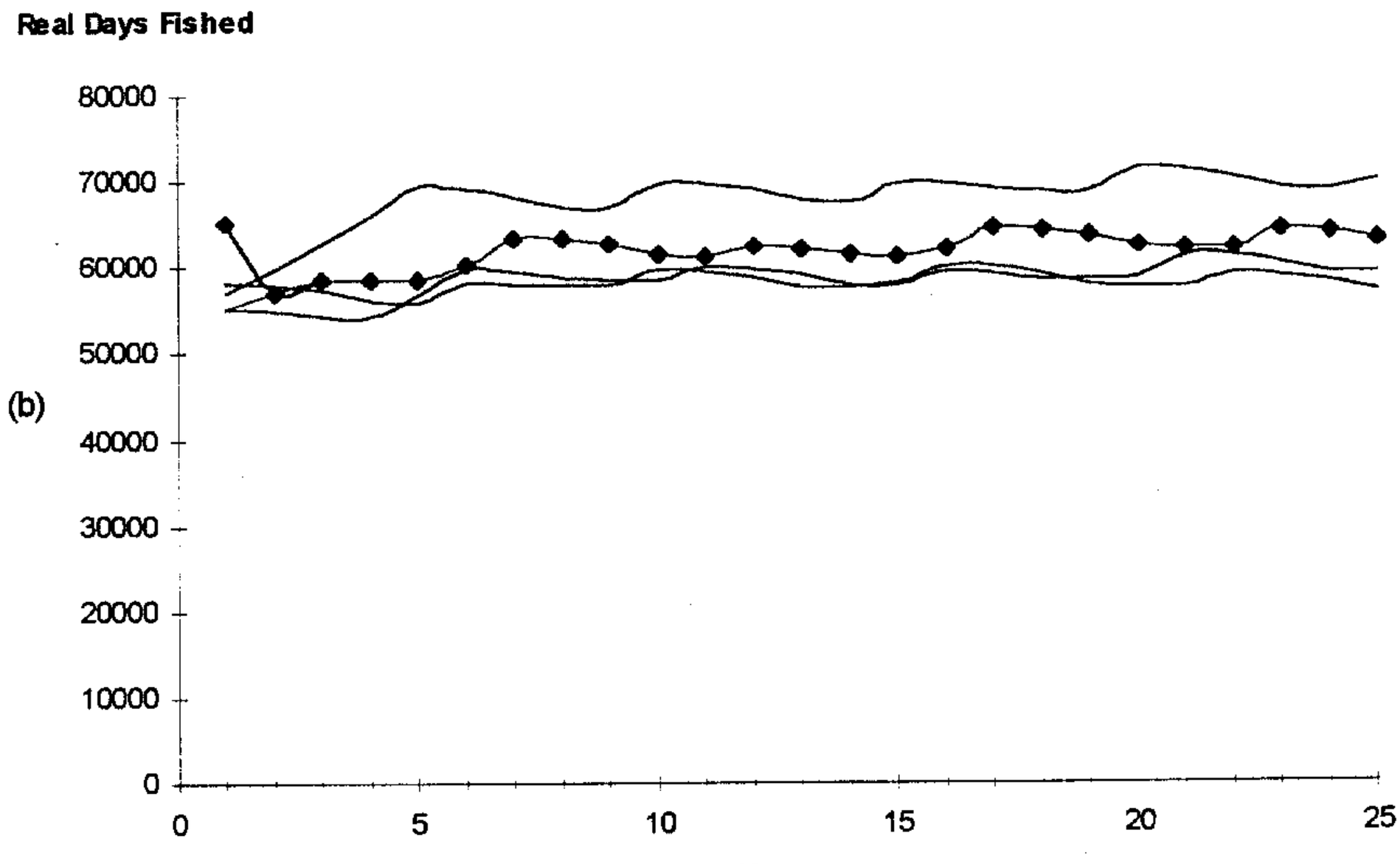




Figure 14. Vessel owner's rent (a) and real days fished (b) for vessel class 5 (length > 55 ft w/headrope > 100 ft)) operating in Texas waters for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)

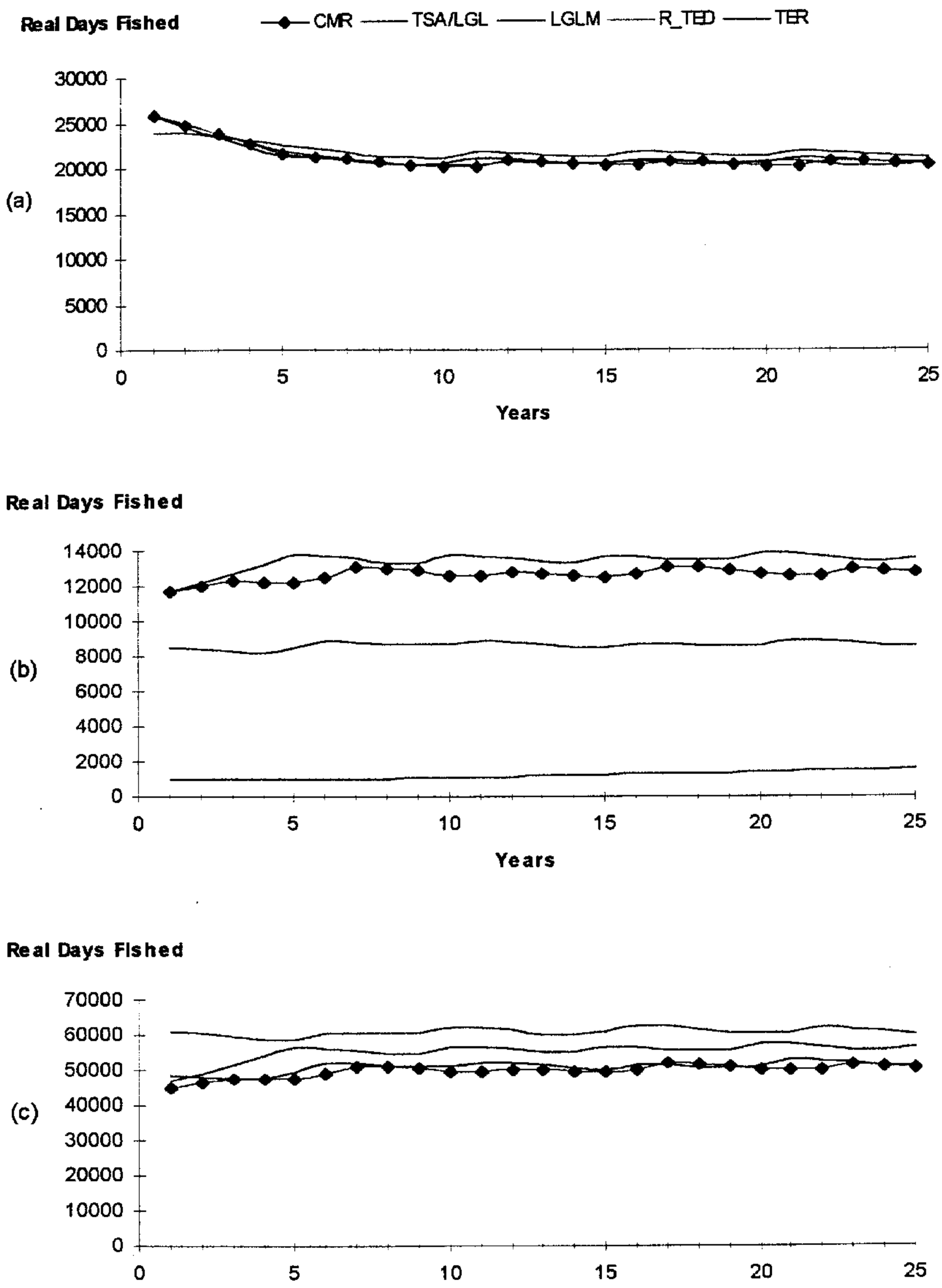



Figure 15. Real days fished in the (a) inshore, (b) nearshore and (c) offshore waters Texas for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)

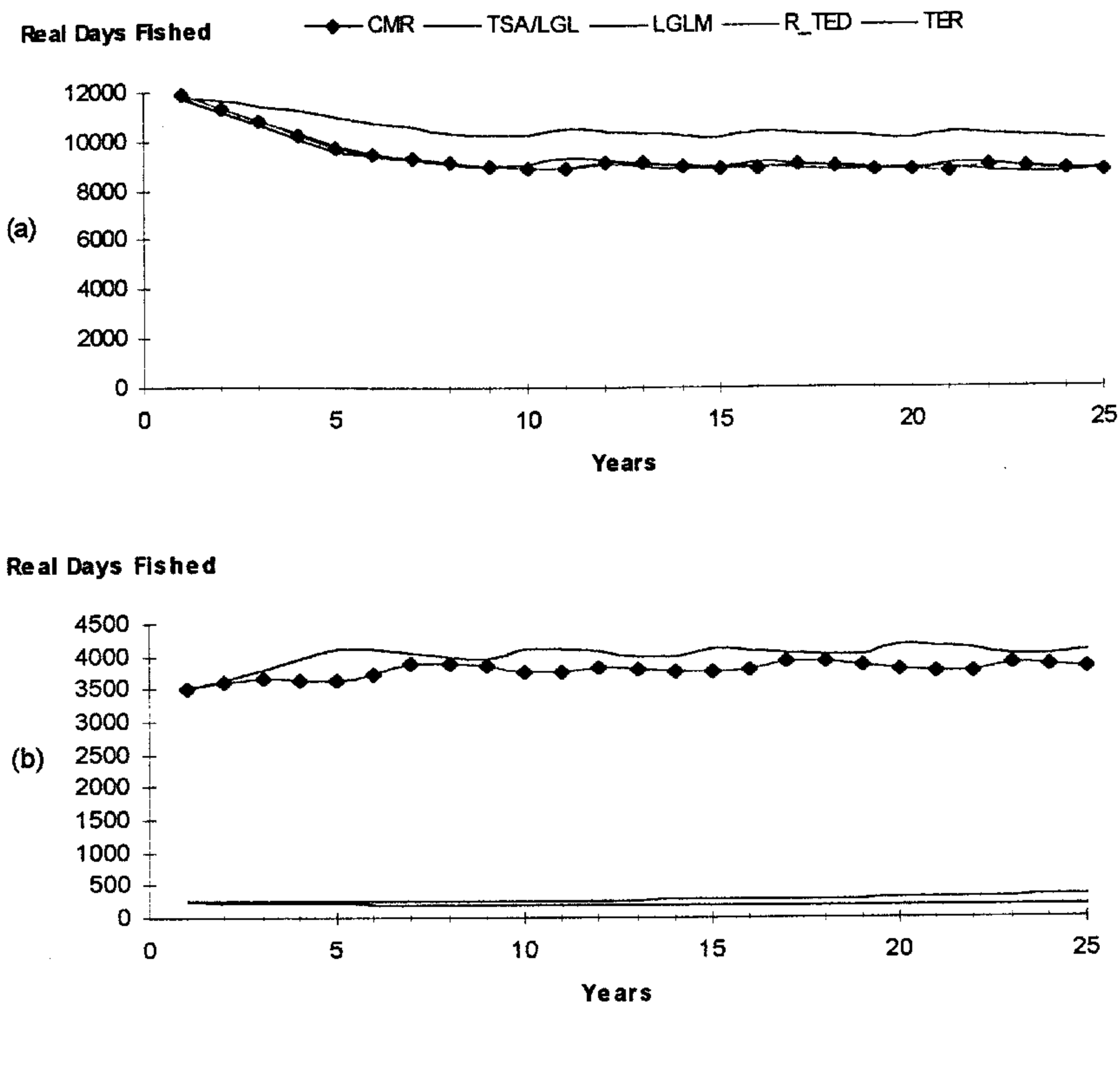



Figure 16. Real days fished during the last week in April through the first week in August in the (a) inshore, (b) nearshore and (c) offshore waters Texas for existing current management regulation (CMR) versus four proposed management alternatives. (CMR and R_TED appears as a single line but are actually two lines.)